



7 CARLO GAVAZZI SPACE SpA

## RICH SYSTEM

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N° Doc.: Doc. N°:	RICSYS-PR-CGS-009	Ediz.: Issue:	3	Data: Date:	16/05/2006	Pagina Page	1 Of 42
Titolo : Title : TOF THERMAL TEST PROCEDURE							

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 <b>CARLO GAVAZZI</b> CARLO GAVAZZI SPACE SpA	<b>RICH SYSTEM</b> TOF THERMAL TEST PROCEDURE	N° Doc: Doc N°:	<b>RICSYS-PR-CGS-009</b>
		Ediz.: Issue:	3      Data: Date: <b>16/05/2006</b>
		Pagina Page	2      di of <b>42</b>

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CARLO GAVAZZI SPACE SpA

# RICH SYSTEM

TOF THERMAL TEST PROCEDURE

N° Doc:  
Doc N°:

RICSYS-PR-CGS-009

Ediz.:  
Issue:

3

Data:

16/05/2006

Pagina  
Page

3

di  
of

42

## LISTA DELLE PAGINE VALIDE / LIST OF VALID PAGES

PAGINA PAGE	EDIZIONE ISSUE								
1 - 40	2								
1 - 42	3								

 <b>CARLO GAVAZZI</b>  CARLO GAVAZZI SPACE SpA	<b>RICH SYSTEM</b>  TOF THERMAL TEST PROCEDURE	N° Doc: Doc N°:	<b>RICSYS-PR-CGS-009</b>
		Ediz.: Issue:	3 Data: Date: <b>16/05/2006</b>
		Pagina Page	4 di of <b>42</b>

## TABLE OF CONTENT

<b>1. SCOPE</b>	<b>6</b>
<b>2. DOCUMENTS</b>	<b>7</b>
<b>2.1 APPLICABLE DOCUMENTS</b>	<b>7</b>
<b>2.2 REFERENCE DOCUMENTS</b>	<b>7</b>
<b>2.3 ACRONYMS</b>	<b>8</b>
<b>3. PARTICIPANTS REQUIRED</b>	<b>9</b>
<b>3.1 GENERAL</b>	<b>9</b>
<b>3.2 RESPONSIBILITY</b>	<b>9</b>
<b>3.3 QA WITNESS OF TEST AND SIGN-OFF</b>	<b>9</b>
<b>3.4 NON CONFORMANCE AND FAILURES</b>	<b>9</b>
<b>3.5 CALIBRATION REQUIREMENTS</b>	<b>9</b>
<b>4. TEST ARTICLE</b>	<b>10</b>
<b>5. FACILITY</b>	<b>10</b>
<b>6. TEST CONFIGURATION</b>	<b>10</b>
<b>6.1 INTERFACES</b>	<b>11</b>
<b>6.2 THERMAL SENSORS</b>	<b>14</b>
<b>6.2.1 FLIGHT SENSORS AND TRP LOCATION</b>	<b>15</b>
<b>6.2.2 EXTERNAL TEST SENSORS LOCATION</b>	<b>17</b>
<b>6.2.3 TEMPERATURE CONTROL POINTS</b>	<b>23</b>
<b>6.3 FUNCTIONAL TESTS</b>	<b>23</b>
<b>7. INSTRUMENTATION AND TEST EQUIPMENT</b>	<b>23</b>
<b>8. TEST CONDITION</b>	<b>25</b>
<b>8.1 MEASUREMENTS ACCURACY</b>	<b>25</b>
<b>9. TEST PROFILE</b>	<b>26</b>
<b>10. TEST SUCCESS CRITERIA</b>	<b>27</b>
<b>11. TEST PROCEDURE VARIATION SHEET</b>	<b>27</b>
<b>12. TEST DATA SHEETS</b>	<b>30</b>
<b>12.1 DATA SHEETS FILLING UP</b>	<b>30</b>
<b>13. ANNEX A: FUNCTIONAL TEST (FOR INFN USE ONLY)</b>	<b>39</b>
<b>14. ANNEX B: PMT +COPPER SHIELD TV-TEST</b>	<b>41</b>
<b>15. ANNEX C: TEMPERATURE LEVEL DEFINITION</b>	<b>42</b>
<b>16. ANNEX D: SERMS FACILITY DESCRIPTION</b>	



CARLO GAVAZZI SPACE SpA

# RICH SYSTEM

## TOF THERMAL TEST PROCEDURE

N° Doc:  
Doc N°:

RICSYS-PR-CGS-009

Ediz.:  
Issue:

3

Data:  
Date: 16/05/2006Pagina  
Page

5

di  
of

42

### LIST OF TABLES

Table 5-1 Temperature sensors location	18
Table 6-1 INSTRUMENT LIST	24
Table 8-1 Temperatures for TOF	26

### LIST OF FIGURES

Figure 5-1 TOF Detector	10
Figure 5-2 Support structure	12
Figure 5-3 TOF assembly, with the honeycomb panel (blue)	12
Figure 5-4 Test Configuration	13
Figure 5-5 TOF coordinate system	14
Figure 5-6 Box +X: Flight Sensors location	15
Figure 5-7 Box -X: Flight Sensors location	15
Figure 5-8 Box +Y: Flight Sensors location	16
Figure 5-9 Box -Y: Flight Sensors location	16
Figure 5-10 Thermal sensors location on lower honeycomb panels	18
Figure 5-11 Thermal sensors location on carbon fiber top panel	19
Figure 5-12 Thermal sensors location on upper lateral box +Y and +X	19
Figure 5-13 Thermal sensors location on upper lateral box -Y and -X	20
Figure 5-14 Thermal sensors location on lower lateral boxes +Y and +X	20
Figure 5-15 Thermal sensors location on lower lateral boxes -Y and -X	21
Figure 5-16 Thermal sensors location on ring support structure	22
Figure 5-17 TV Chamber minimal thermal sensors layout	22
Figure 5-18 CP location on the lateral boxes (+/-Y)	23
Figure 8-1 Thermal Vacuum Cycling and Thermal Balance Test profile(for the temperature level see Table 8-1)	27
Figure 12-1 TV Chamber Flange Cabling	39
Figure 12-2 Functional Test Setup	40



CARLO GAVAZZI SPACE SpA

## RICH SYSTEM

TOF THERMAL TEST PROCEDURE

N° Doc:  
Doc N°:

RICSYS-PR-CGS-009

Ediz.:  
Issue:

3

Data:

16/05/2006

Pagina  
Page

6

di  
of

42

### 1. SCOPE

This document describes the procedure applicable to the Thermal Vacuum Cycling (TVC) and Thermal Balance tests (TB) of the Time of Flight detector (TOF) equipment, which is part of Alpha Magnetic Spectrometer (AMS02) flight unit, to be performed during the acceptance campaign in accordance with AD[2].

The main objectives of the test are:

- To test the internal thermal design of the TOF (conductive and radiative links within the flight unit) in hot and cold conditions
- To verify the heater power budget and the thermostats performances
- To define the minimum environmental temperature that the non operative TOF can experience
- To validate the thermal mathematical models (TMM and GMM)

Additionally a cold / hot environment is provided to the payload developer (INFN) to:

- demonstrate the ability of equipment to operate when exposed to extreme operational temperatures after being exposed to extreme non-operational in vacuum environment.
- test the workmanship

In order to get these target the test consists of:

- Four cycles in vacuum chamber, the fourth cycle plateau will be extended in time in order to allow the TB stabilization criteria verification in order to perform the TMM/GMM correlation.
- An additional part at cold temperature dedicated to the heater/thermostats verification and minimum non operative temperature definition..

Before, during and after the test, the functional performance of the test item shall be checked in order to reveal potential functional degradation or malfunction. The functional test sequence the UUT shall undergo is under responsibility of INFN personnel.

The test results shall be collected in a dedicated Test Report. The test report shall not include the detailed functional test results



CARLO GAVAZZI SPACE SpA

# RICH SYSTEM

## TOF THERMAL TEST PROCEDURE

N° Doc:  
Doc N°:

RICSYS-PR-CGS-009

Ediz.:  
Issue:3 Data:  
Date: 16/05/2006Pagina  
Page 7 di  
of 42

## 2. DOCUMENTS

### 2.1 APPLICABLE DOCUMENTS

AD#	Doc Number	Issue	Date	Rev	Title
AD 1	AMS02-TN-004-CGS	3	19/05/2004		Preliminary thermal requirement for internal AMS02 interfaces
AD 2	Contratto I/020/03/0		14/05/2003		Allegato tecnico-gestionale al contratto

### 2.2 REFERENCE DOCUMENTS

RD#	Doc Number	Issue	Date	Rev	Title
RD 1	RICSYS-RP-CGS-008	1	30/09/2003		TOF Thermal control system design report
RD 2	GD-PL-CGS-001	3	17/03/1999		Product Assurance & RAMS Plan
RD 3	ECSS-E10-03A		15/02/2002		Space engineering- Testing
RD 4	621-RICH 1913		5/4/2006		Fax from F. Palmonari to CGS: temperature levels, ANNEX C



CARLO GAVAZZI SPACE SpA

# RICH SYSTEM

## TOF THERMAL TEST PROCEDURE

N° Doc:  
Doc N°:

RICSYS-PR-CGS-009

Ediz.:  
Issue:

3

Data:  
Date:

16/05/2006

Pagina  
Page

8

di  
of

42

### 2.3 ACRONYMS

AD	Applicable Document
AMS	Alpha Magnetic Spectrometer
CGS	Carlo Gavazzi Space
CI	Configuration Item
CP	Control Point
DAQ	Data Acquisition
EGSE	Electronic Ground Segment Equipment
FM	Flight Model
FT	Functional Test
GMM	Geometrical Mathematical Model
MLI	Multi Layer Insulator
NA	Not Applicable
NCR	Non Conformance Report
P/N	Part Number
PA	Product Assurance
PFM	Protoflight Qualification Model
PMT	Photo Multiplier T
PVS	Procedure Variation Sheet
QA	Quality Assurance
RD	Reference Document
RICH	Ring Image Cherenkov Counter
SFEC	Scintillator Front End Charge
S/N	Serial Number
TB	Thermal Balance Test
TBC	To Be Confirmed
TBD	To Be Defined
TBW	To Be Written
TMM	Thermal Mathematical Model
TOF	Time of Flight
TRP	Temperature Reference Point
TV	Thermal Vacuum
TVC	Thermal Vacuum Cycling Test
USS	Unique Support Structure
UUT	Unit Under test



CARLO GAVAZZI SPACE SpA

# RICH SYSTEM

TOF THERMAL TEST PROCEDURE

N° Doc:  
Doc N°: RICSYSPR-CGS-009  
Ediz.: 3 Data: 16/05/2006  
Issue:  
Pagina 9 di 42  
Page

## 3. PARTICIPANTS REQUIRED

### 3.1 GENERAL

All test will be performed under QA surveillance in accordance with, and following detailed procedure of applicable Product Assurance (PA) Plan. Start of the Test shall be notified to Prime Contractor and/or Customer as applicable.

### 3.2 RESPONSIBILITY

The technical responsibility for testing and test results reporting is up to the **Technical Directorate of CGS**. The test shall be run by skilled personnel under the surveillance of the CGS Technical Directorate which will provide the test conductor.

Continuous witness of the test will be ensured by means of shifts: CGS Thermal Department will be providing a continuous presence when running the step-by-step procedure described in the paragraph 11.

**CGS QA** is responsible for ensuring that all the agreed procedures are carefully observed, that test equipment and instrumentation used during testing is calibrated and within validity date; that the test data sheets are recorded in the Test Report and signed by the operators and QA witnesses, that all non-conforming condition and test results are properly documented and notified to the Prime Contractor, and that all requirements of applicable PA Plan, specification and Statement of Work pertaining to the tests, are fully satisfied.

**INFN-Bologna**, being responsible of the design (with exception of the thermal control system) of the TOF, will provide personnel to operate the TOF detector (switching ON/OFF the instrument, verifying the performances, conduct the functional test).

**Facility personnel**, based on test conductor input, shall operate the TV-Chamber in order to guarantee the test temperature level requirement are met

### 3.3 QA WITNESS OF TEST AND SIGN-OFF

QA Inspector, or its delegate, shall witness the tests described in this procedure in accordance to the requirement specified in the applicable PA Plans

### 3.4 NON CONFORMANCE AND FAILURES

Any malfunction/defect which occurs during the test will be processed along the Non Conformance Procedure described in the applicable PA Plans.

### 3.5 CALIBRATION REQUIREMENTS

All instruments used for testing shall be calibrated.

Evidence of certification shall be provided by a label attached to the instruments itself, showing the calibration date, the expiring date and the signature of the operator.

All calibration certificates will be provided by the external facility upon request, in the facility test report.



CARLO GAVAZZI SPACE SpA

## RICH SYSTEM

TOF THERMAL TEST PROCEDURE

N° Doc:  
Doc N°:  
Ediz.:  
Issue:  
Pagina  
PageRICSYS-PR-CGS-009  
3 Data: 16/05/2006  
10 di 42

### 4. TEST ARTICLE

The test article consists on the FM of the TOF Detector of AMS02.  
It shall be tested according to this procedure with the required procedure variation sheets.

The P/N of the test article(s) to be tested shall be recorded before starting the test on the step by step procedure sheets under "UNIT UNDER TEST" (UUT) table cell.

### 5. FACILITY

The selected test Facility is Università di Perugia (Polo scientifico Didattico di Temi, Laboratorio SERMS), in Temi – Italy.

It is an external facility. See annex D for the details about the facility.

### 6. TEST CONFIGURATION

TOF in flight configuration will be provided by INFN Heaters and thermostats have been provided by CGS and are integrated in their flight configuration.

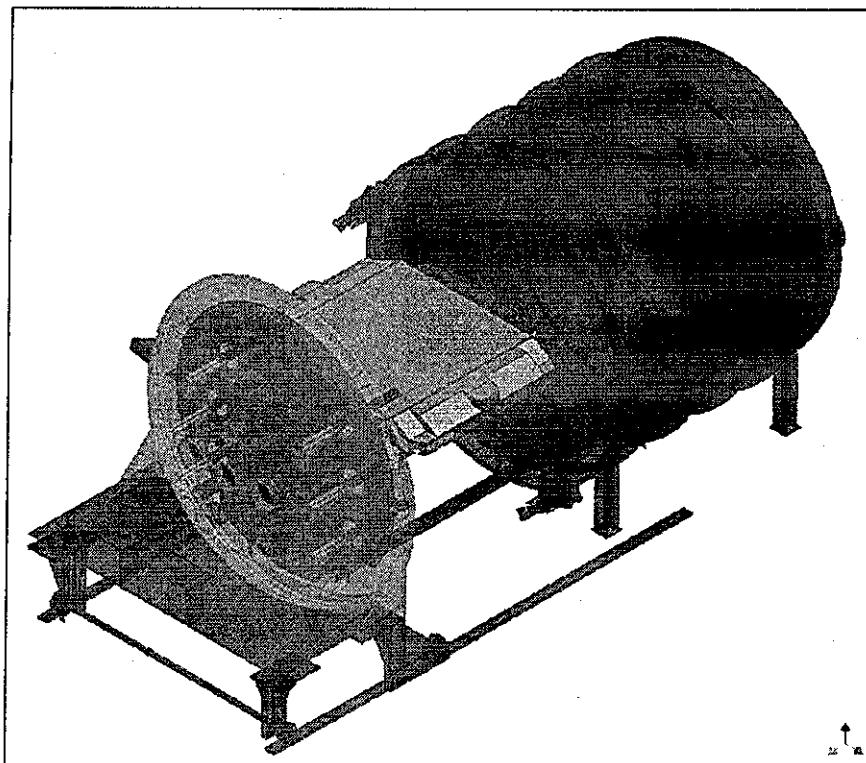


Figure 6-1 TOF Detector in the thermal-vacuum chamber

TOF will be moved into a Thermal Vacuum (TV) Chamber by the means of an appropriate crane and mounted on a dedicated support structure fixed to the chamber fixture.

In the next figure the test configuration is shown. In parenthesis the responsibility is indicated for each item to be provided for the test.

TOF will not have the FM MLI -which is shared with other subdetectors and cannot be physically installed on the standalone TOF- and will be supported by 4 insulating feet, put on the facility rails.



CARLO GAVAZZI SPACE SpA

# RICH SYSTEM

## TOF THERMAL TEST PROCEDURE

N° Doc:  
Doc N°:

RICSYS-PR-CGS-009

Ediz :  
Issue:

3

Data:  
Date: 16/05/2006Pagina  
Page:

11

di  
of 42

The TOF will be thermally coupled to the TV chamber shroud by radiation only, as this will be the typical heat transfer in flight conditions.

EGSE will be used to supply power to the TOF and allow science data acquisition, by INFN.

The TOF shall be connected to the relevant Electronic Ground Segment Equipment (EGSE) and supplied at the nominal operating voltage by INFN as well.

TOF switch-on and switch-off and all the functional verifications are by INFN and under responsibility of INFN, both for what concern the execution and the results.

Functional test results are not to be used as a success criterion for the CGS thermal test.

The Facility will provide:

- temperature sensors
- data acquisition and recording system

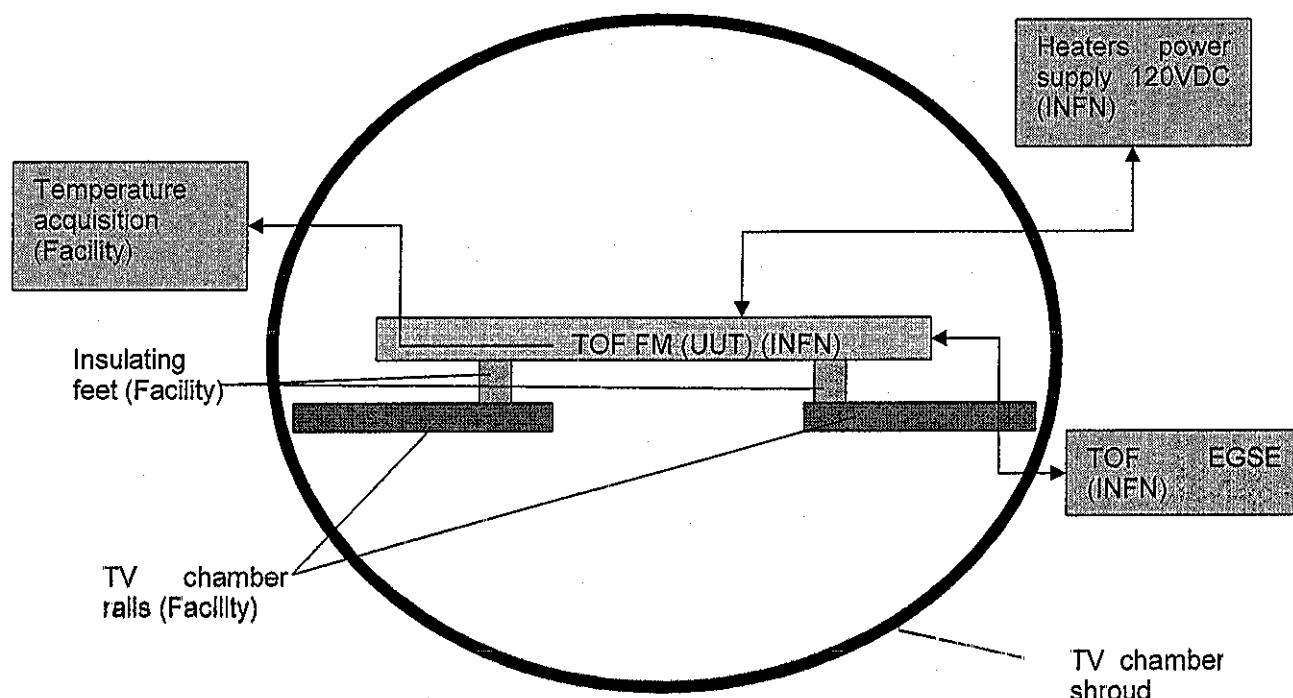


Figure 6-2 Test configuration

The TV Chamber used shall be capable to set the shroud temperature in a adequate range. The fixture temperature will change passively with the shroud one.

Test set up are described in the step-by-step procedure sheets provided in section 12.1.

### 6.1 INTERFACES

The following figure shows the dedicated support structure made of an aluminium frame and Teflon insulating supports sized in order to minimize the conductive heat exchange between UUT and the TV Chamber rails



CARLO GAVAZZI SPACE SpA

# RICH SYSTEM

TOF THERMAL TEST PROCEDURE

N° Doc:  
Doc N°:

RICSYS-PR-CGS-009

Ediz.:  
Issue:

3

Data:  
Date: 16/05/2006Pagina  
Page

12

di  
of 42

The following figures show the support structure.

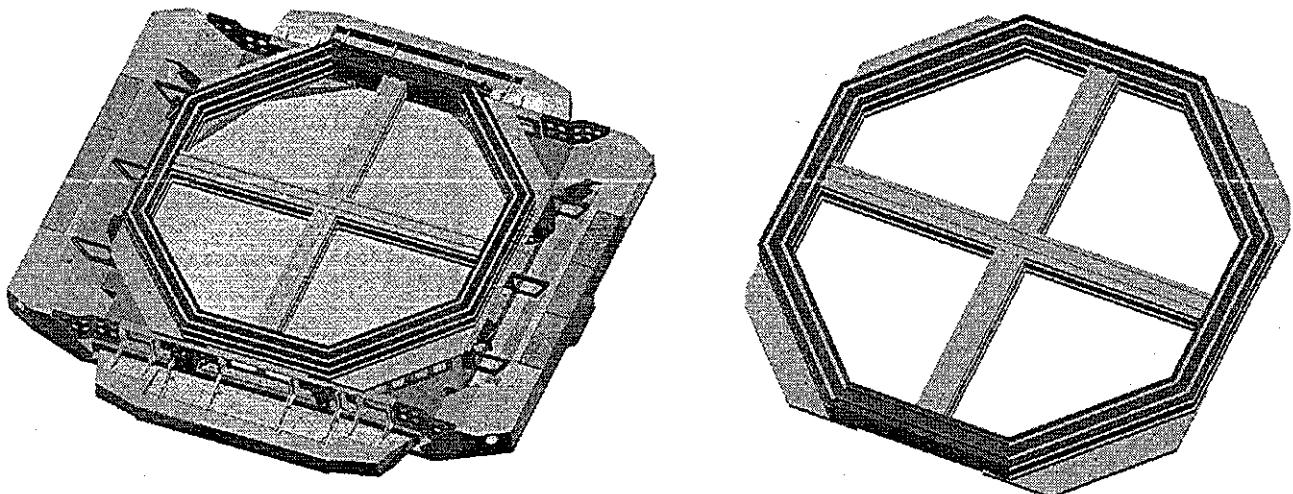


Figure 6-3 Support structure

The in Figure 6-5 shows the UUT will. The heat exchange will be mainly via radiation. The FM model of TOF alone will be let free to radiate toward the chamber shroud.

The chamber temperature will be set in order to impose the required temperature onto the TRP.

HONEYCOMB PANEL

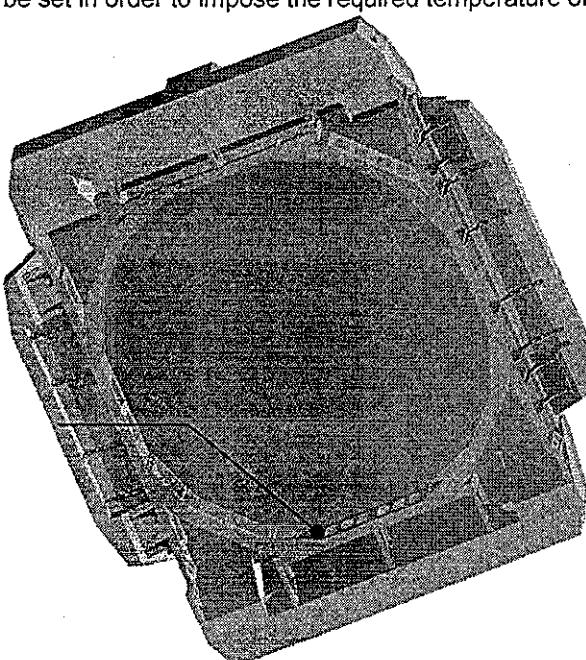


Figure 6-4 TOF assembly, with the honeycomb panel (blue)



CARLO GAVAZZI SPACE SpA

# RICH SYSTEM

TOF THERMAL TEST PROCEDURE

N° Doc:  
Doc N°:

RICSYS-PR-CGS-009

Ediz :  
Issue:

3 Data:  
Date: 16/05/2006

Pagina  
Page

13 di  
of 42

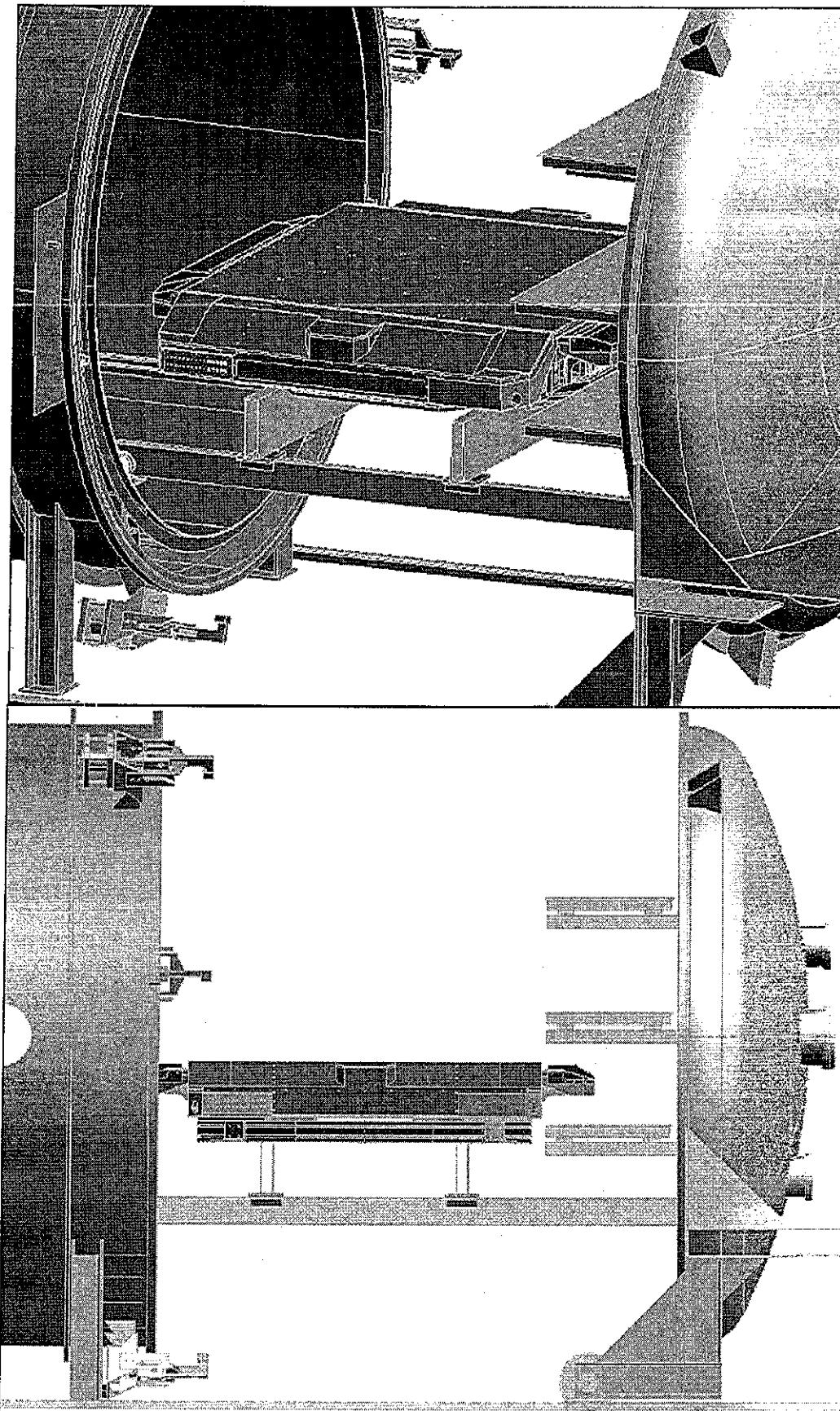


Figure 6-5 Test Configuration



CARLO GAVAZZI SPACE SpA

# RICH SYSTEM

TOF THERMAL TEST PROCEDURE

N° Doc:  
Doc N°:

RICSYS-PR-CGS-009

Ediz.:  
Issue:

3

Data:  
Date:

16/05/2006

Pagina  
Page

14

di  
of

42

## 6.2 THERMAL SENSORS

Three different kind of thermal sensors are foreseen during the test:

- 16 Flight Dallas Sensors; they are located internally on PMT Copper Shield and SFEC
- 14 Test Sensors (PT100) : located internally in the same position of the Flight Dallas sensors on SFEC and PMT Copper Shield. The sensor on the PMT Copper Shield represent also the TRP of the test.
- 44 Test Sensors (PT100): they are located externally

In the following paragraphs the different part of the TOF will be defined accordingly to this coordinate system:

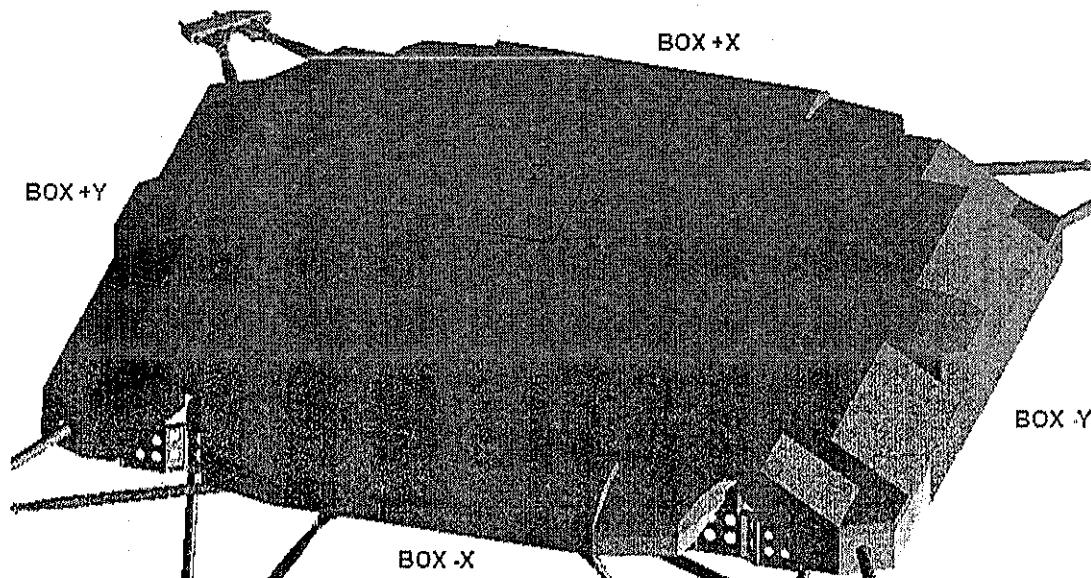


Figure 6-6 TOF coordinate system



CARLO GAVAZZI SPACE SpA

# RICH SYSTEM

TOF THERMAL TEST PROCEDURE

N° Doc:  
Doc N°:

RICSYS-PR-CGS-009

Ediz.:  
Issue:3 Data:  
Date: 16/05/2006Pagina  
Page15 di  
of 42

## 6.2.1 FLIGHT SENSORS AND TRP LOCATION

The PMTs are placed Inside the TOF, they have a Copper Shield where the flight temperature sensors (Dallas sensors) are located. In order to verify the correct calibration of the flight sensor, 14 test sensor (Pt100) shall be placed in the same position of the Dallas sensor.

The Copper Shields are the TRP (Temperature Reference Points) of the test.

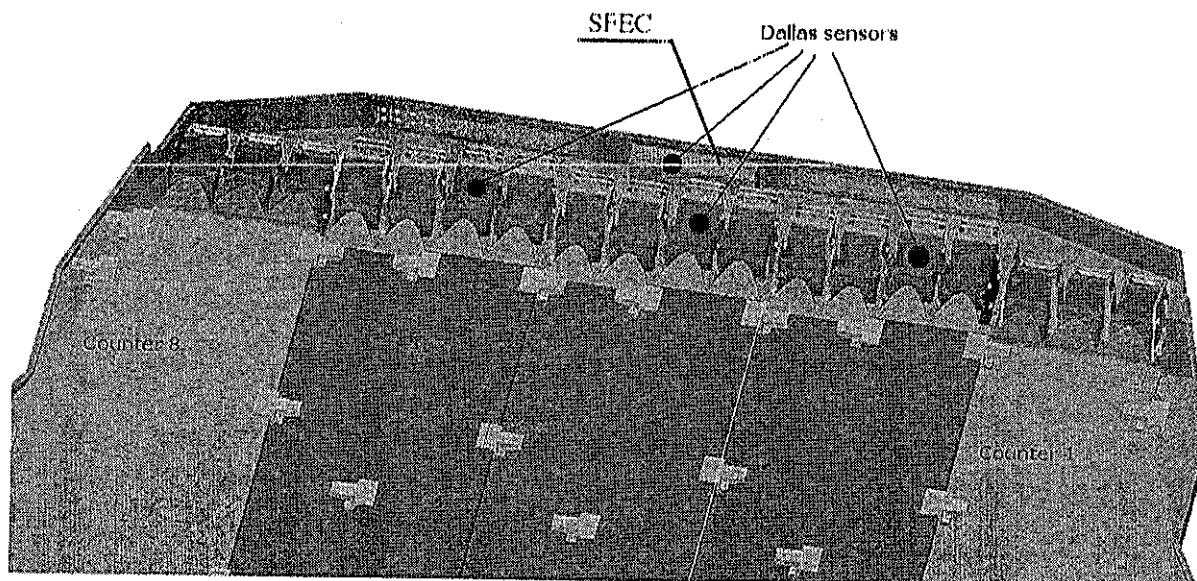


Figure 6-7 Box +X: Flight Sensors location

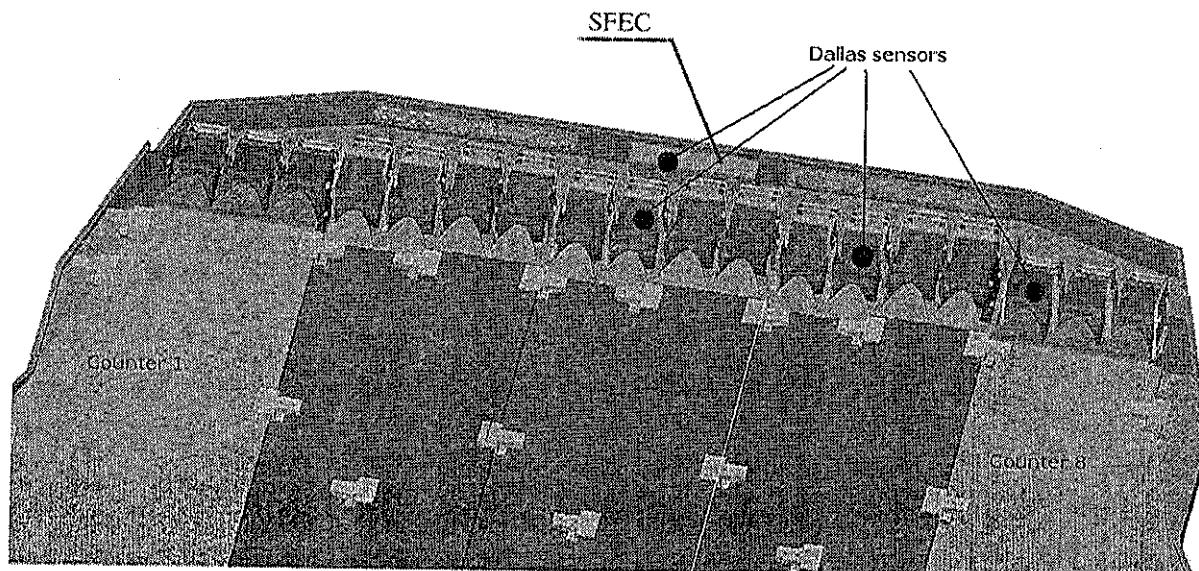


Figure 6-8 Box -X: Flight Sensors location



CARLO GAVAZZI SPACE SpA

# RICH SYSTEM

TOF THERMAL TEST PROCEDURE

N° Doc:  
Doc N°:

RICSYS-PR-CGS-009

Ediz.:  
Issue:

3

Data:  
Date:

16/05/2006

Pagina  
Page

16

di  
of

42

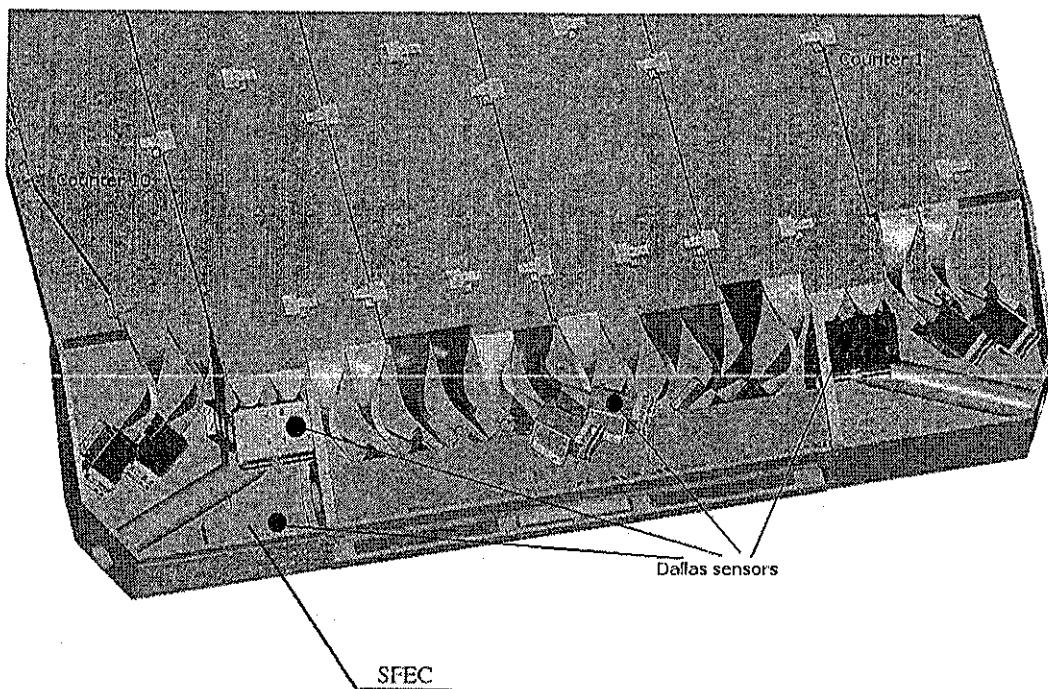


Figure 6-9 Box +Y: Flight Sensors location

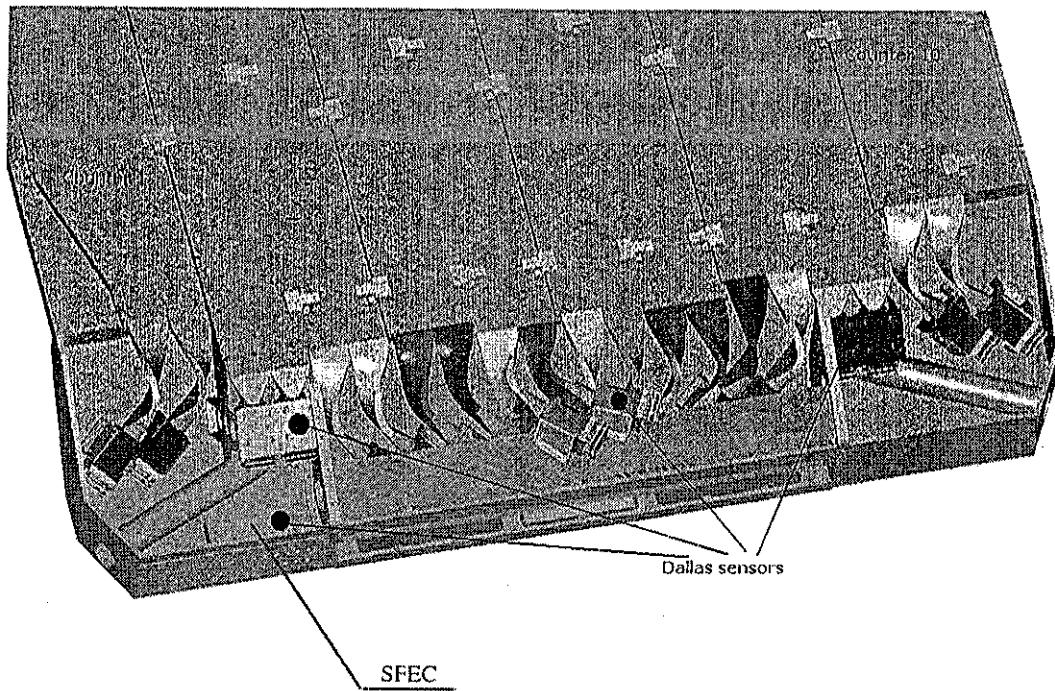


Figure 6-10 Box -Y: Flight Sensors location



CARLO GAVAZZI SPACE SpA

# RICH SYSTEM

## TOF THERMAL TEST PROCEDURE

N° Doc:  
Doc N°:

RICSYS-PR-CGS-009

Ediz.:  
Issue:

3

Data:  
Date:

16/05/2006

Pagina  
Page

17

di  
of

42

### 6.2.2 EXTERNAL TEST SENSORS LOCATION

In addition to these flight sensors, at least 44 test sensors will be placed on the TOF unit and their positions are described in Table 6-1 and can be seen from Figure 6-11 to Figure 6-17.

At least the following sensors shall be used:

Sensor	Position
1.	Lower honey comb panel center
2.	Lower honey comb panel center (red.)
3.	Lower honey comb panel first corner
4.	Lower honey comb panel first corner (red.)
5.	Lower honey comb panel second corner
6.	Lower honey comb panel second corner (red.)
7.	Carbon fiber top panel center
8.	Carbon fiber top panel center (red.)
9.	Carbon fiber top panel first corner
10.	Carbon fiber top panel first corner (red.)
11.	Carbon fiber top panel second corner
12.	Carbon fiber top panel second corner (red.)
13.	Carbon fiber upper/left side lateral box +Y (CP)
14.	Carbon fiber upper/ right side lateral box +Y (CP red.)
15.	Carbon fiber lateral/ left side lateral box +Y
16.	Carbon fiber lateral/ right side lateral box +Y
17.	Carbon fiber upper/ left side lateral box +X (CP)
18.	Carbon fiber upper/ right side lateral box +X (CP red.)
19.	Carbon fiber lateral/ left side lateral box +X
20.	Carbon fiber lateral/ right side lateral box +X
21.	Carbon fiber upper/ left side lateral box -Y (CP red.)
22.	Carbon fiber upper/ right side lateral box -Y (CP red.)
23.	Carbon fiber lateral/ left side lateral box -Y
24.	Carbon fiber lateral/ right side lateral box -Y
25.	Carbon fiber upper/ left side lateral box -X (CP)
26.	Carbon fiber upper/ right side lateral box -X (CP red.)
27.	Carbon fiber lateral/ left side lateral box -X
28.	Carbon fiber lateral/right side lateral box -X
29.	Lower/ left side lateral box +X
30.	Lower/center side lateral box +X
31.	Lower/ right side lateral box +X
32.	Lower/ left ordinate lateral box +Y
33.	Lower/ right ordinate lateral box +Y
34.	Lower/center lateral box +Y
35.	Lower/ left side lateral box -X



CARLO GAVAZZI SPACE SpA

# RICH SYSTEM

## TOF THERMAL TEST PROCEDURE

N° Doc:  
Doc N°:

RICSYS-PR-CGS-009

Ediz.:  
Issue:

3

Data:  
Date:

16/05/2006

Pagina  
Page

18

di  
of

42

36.	Lower/center side lateral box -X
37.	Lower/ right side lateral box -X
38.	Lower/ left ordinate lateral box -Y
39.	Lower/ right ordinate lateral box -Y
40.	Lower/center lateral box -Y
41.	Ring support structure side +X
42.	Ring support structure side +Y
43.	Ring support structure side -X
44.	Ring support structure side -Y
A	TV Chamber bottom wall
B	TV Chamber left wall
C	TV Chamber top wall
D	TV Chamber right wall
E	TV Chamber rear wall
F	TV Chamber front wall

Table 6-1 Temperature sensors location

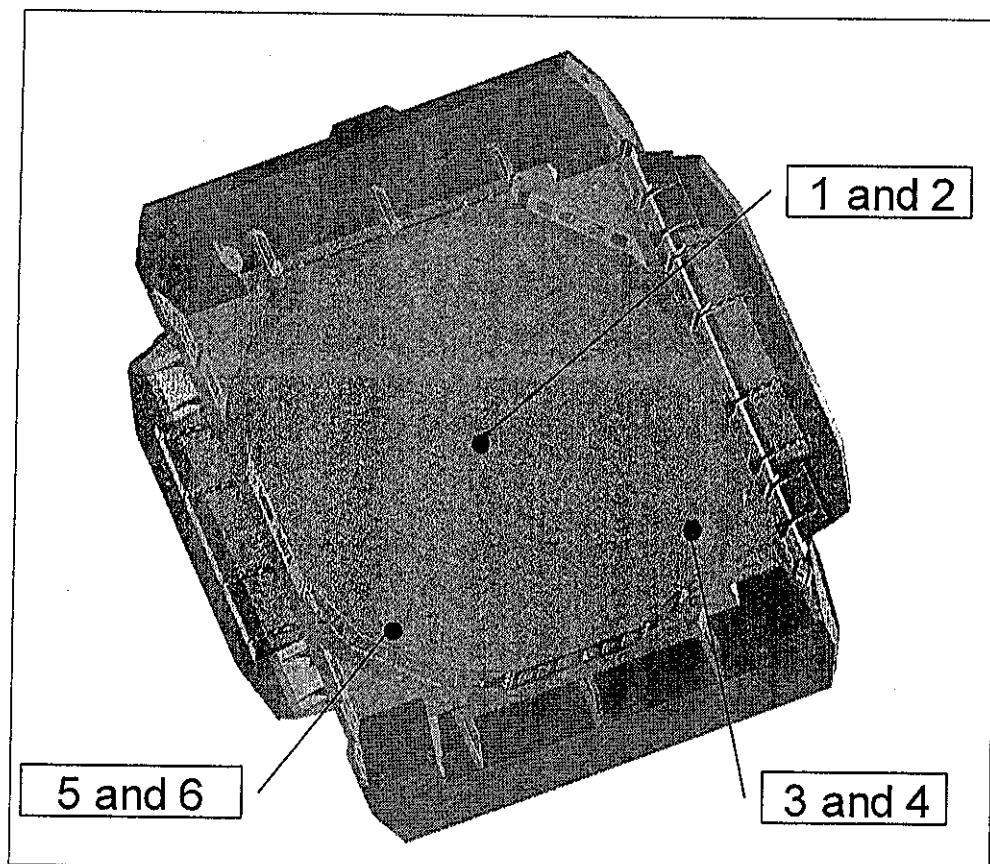


Figure 6-11 Thermal sensors location on lower honeycomb panels.



CARLO GAVAZZI SPACE SpA

# RICH SYSTEM

## TOF THERMAL TEST PROCEDURE

N° Doc:  
Doc N°:

RICSYS-PR-CGS-009

Ediz.:  
Issue:

3 Data:  
Date: 16/05/2006

Pagina  
Page

19 di  
of 42

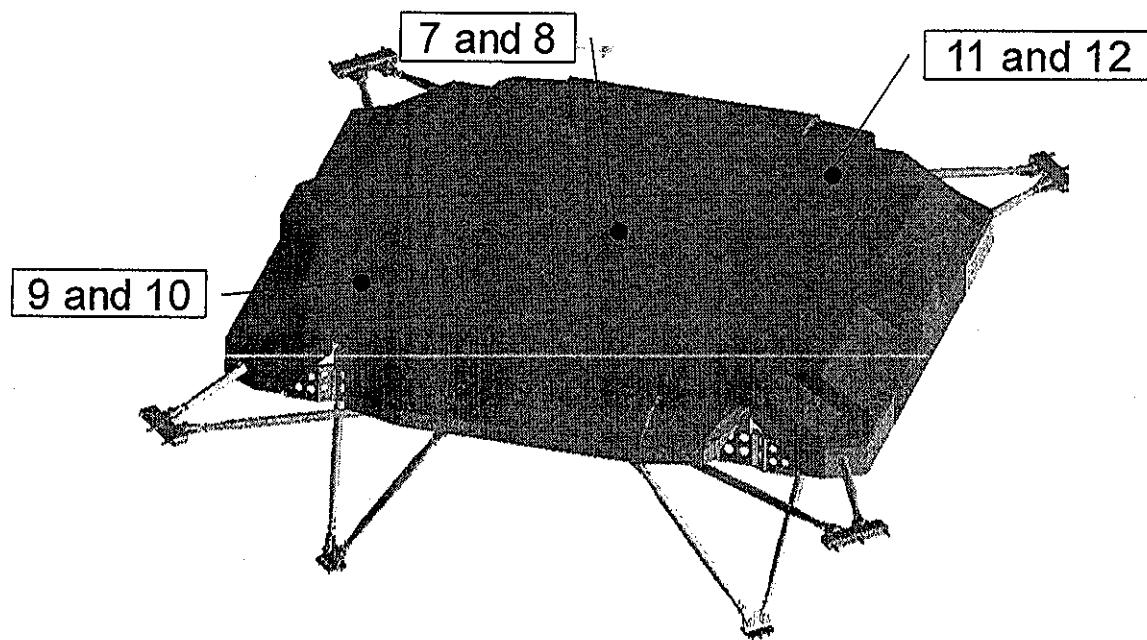


Figure 6-12 Thermal sensors location on carbon fiber top panel

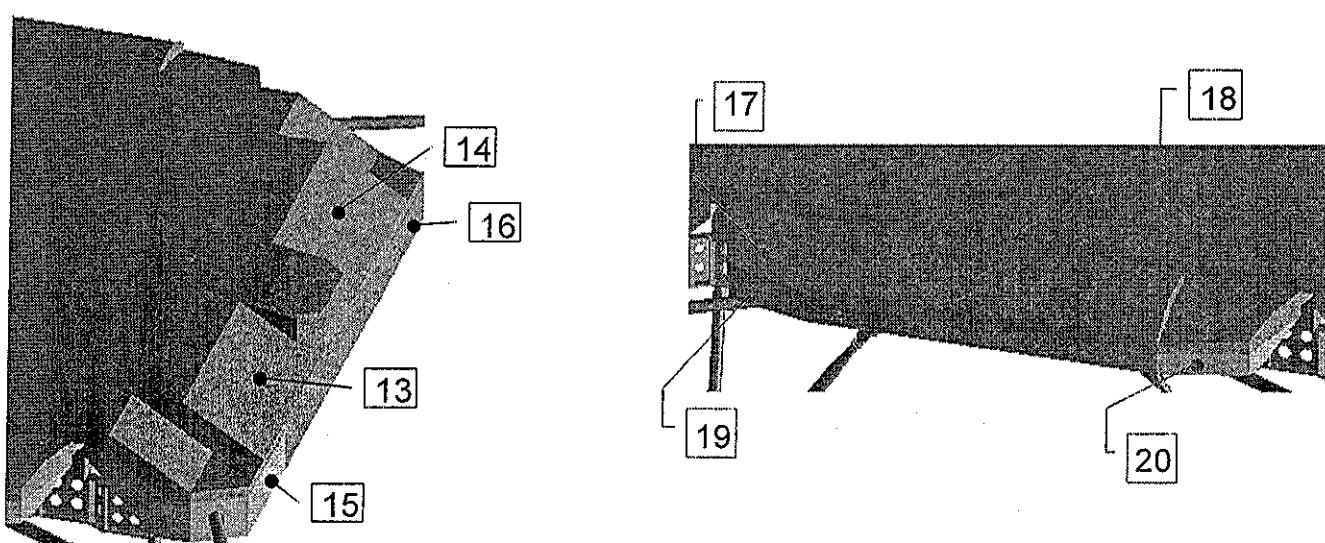


Figure 6-13 Thermal sensors location on upper lateral box +Y and +X



CARLO GAVAZZI SPACE SpA

# RICH SYSTEM

TOF THERMAL TEST PROCEDURE

N° Doc:  
Doc N°:

RICSYS-PR-CGS-009

Ediz.:  
Issue:

3 Data: 16/05/2006

Pagina  
Page

20 di 42

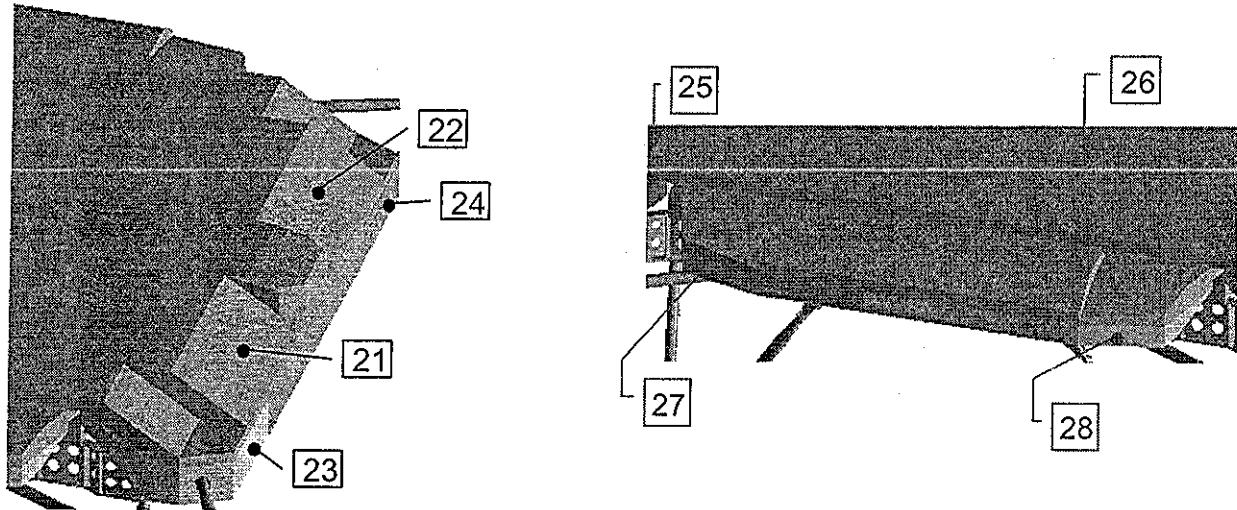


Figure 6-14 Thermal sensors location on upper lateral box -Y and -X

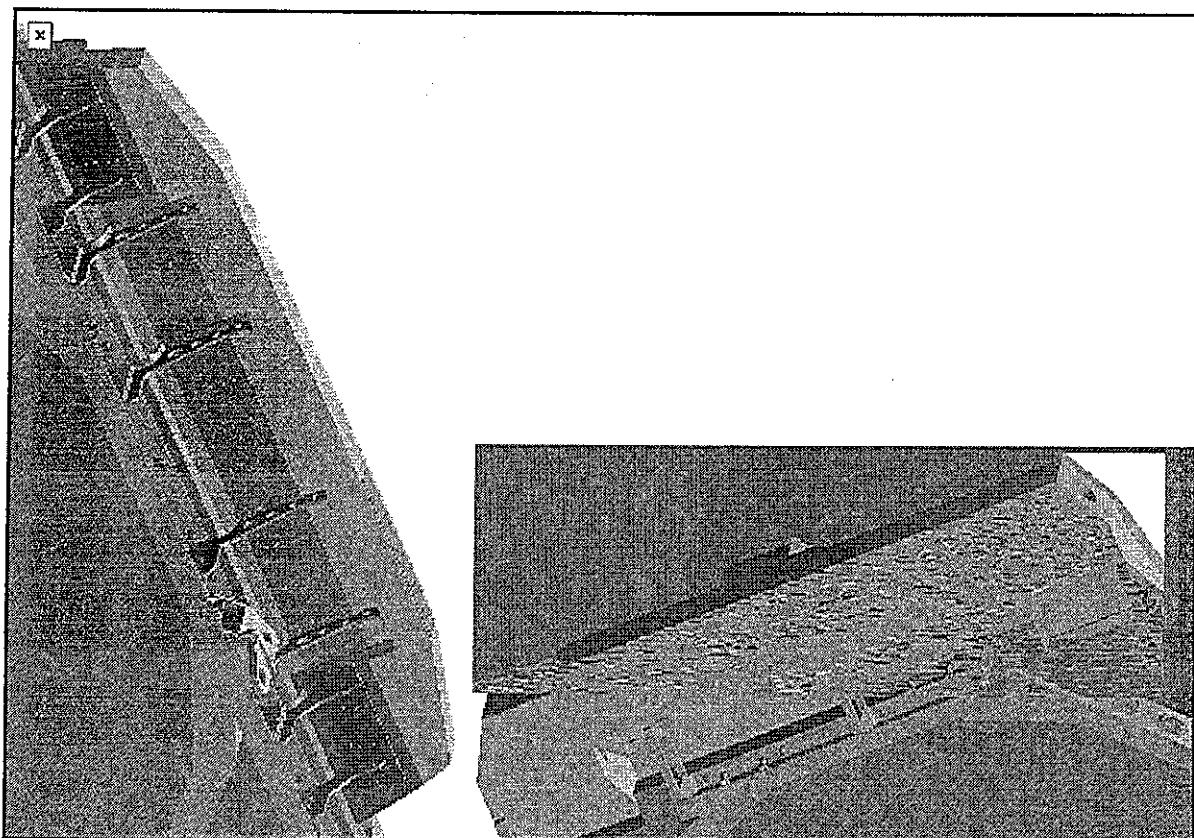


Figure 6-15 Thermal sensors location on lower lateral boxes +Y and +X



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# RICH SYSTEM

TOF THERMAL TEST PROCEDURE

N° Doc:  
Doc N°:

RICSYS-PR-CGS-009

Ediz.:  
Issue:

3

Data:  
Date:

16/05/2006

Pagina  
Page

21

di  
of

42

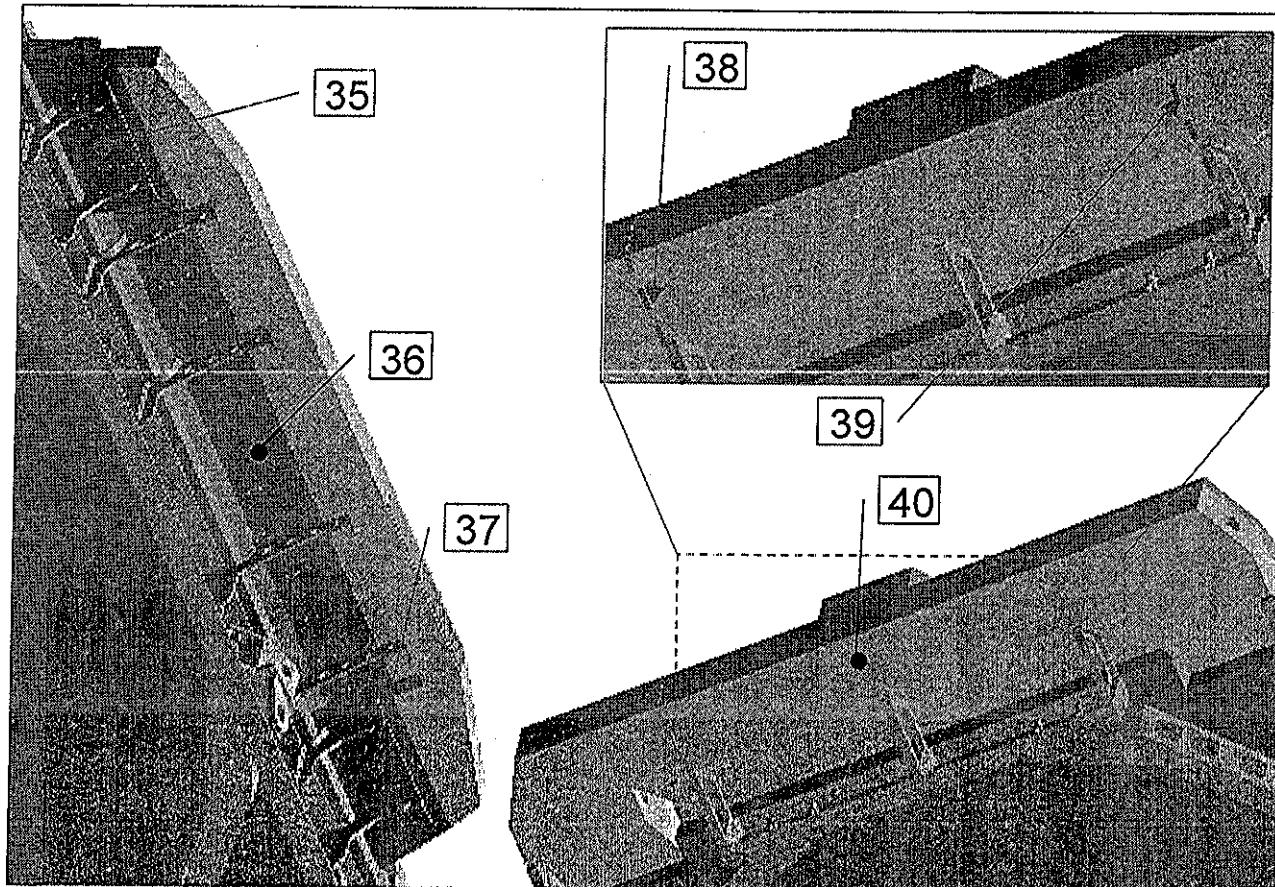


Figure 6-16 Thermal sensors location on lower lateral boxes -Y and -X



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## RICH SYSTEM

TOF THERMAL TEST PROCEDURE

N° Doc: RICSYS-PR-CGS-009  
Doc N°:  
Ediz: 3 Data: 16/05/2006  
Issue:  
Pagina 22 di 42  
Page

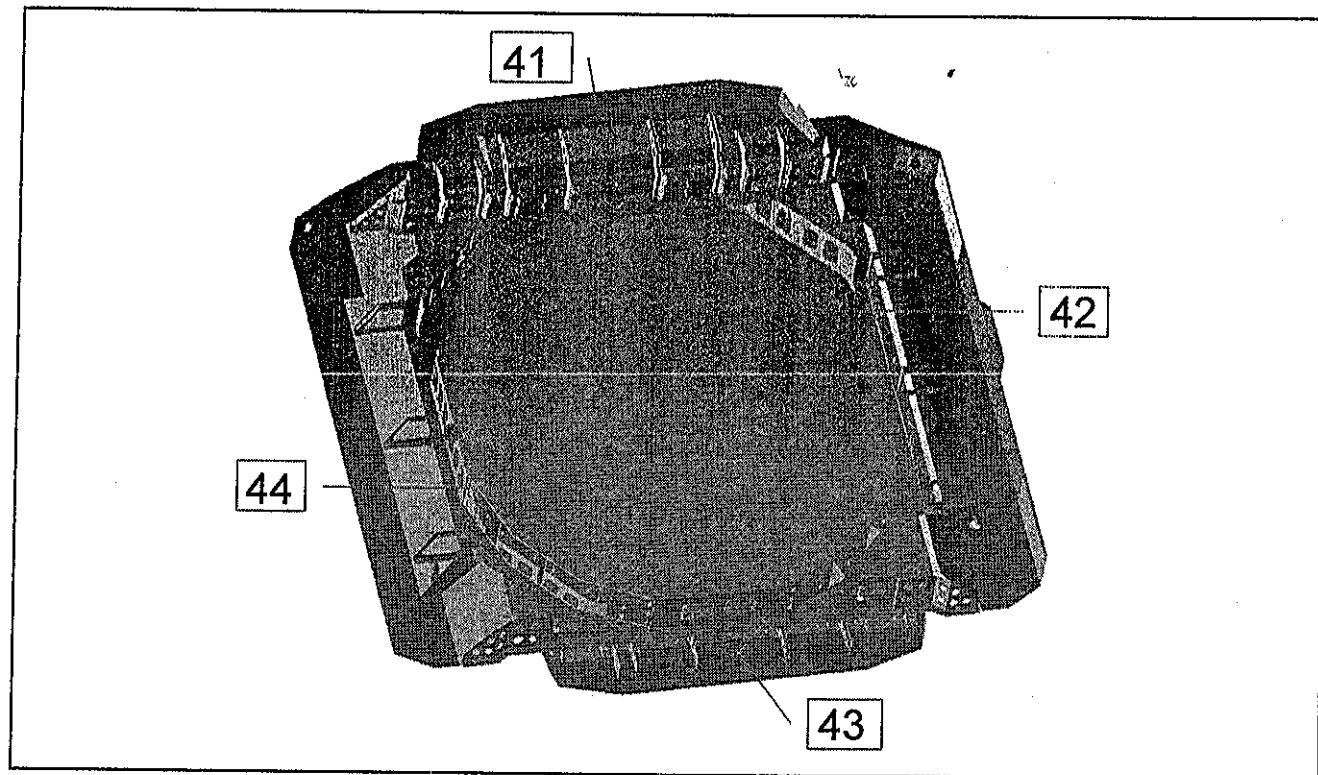


Figure 6-17 Thermal sensors location on ring support structure

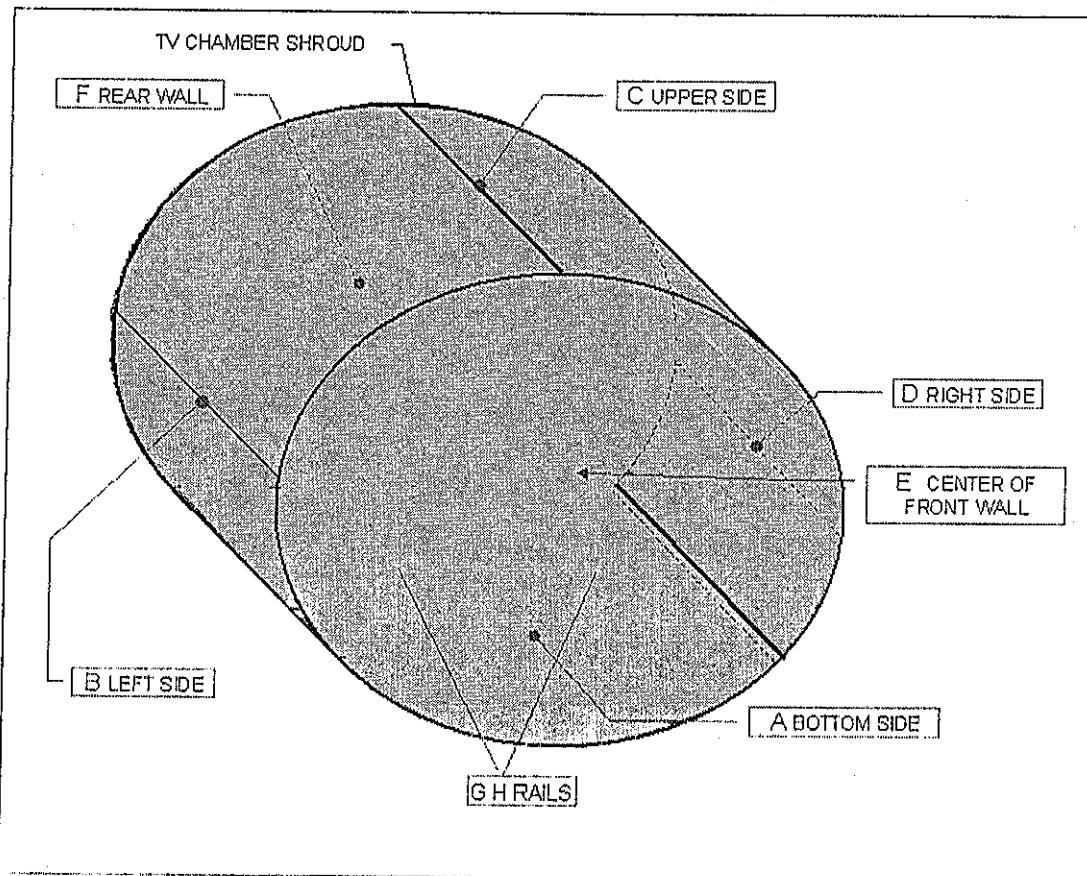


Figure 6-18 TV Chamber minimal thermal sensors layout



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# RICH SYSTEM

## TOF THERMAL TEST PROCEDURE

N° Doc: RICSYS-PR-CGS-009  
Doc N°:  
Ediz: 3 Data: 16/05/2006  
Issue:  
Pagina 23 di 42  
Page:

### 6.2.3 TEMPERATURE CONTROL POINTS

The Control Points (CP) for the test will be on the external box.  
The location is shown in the following pictures.

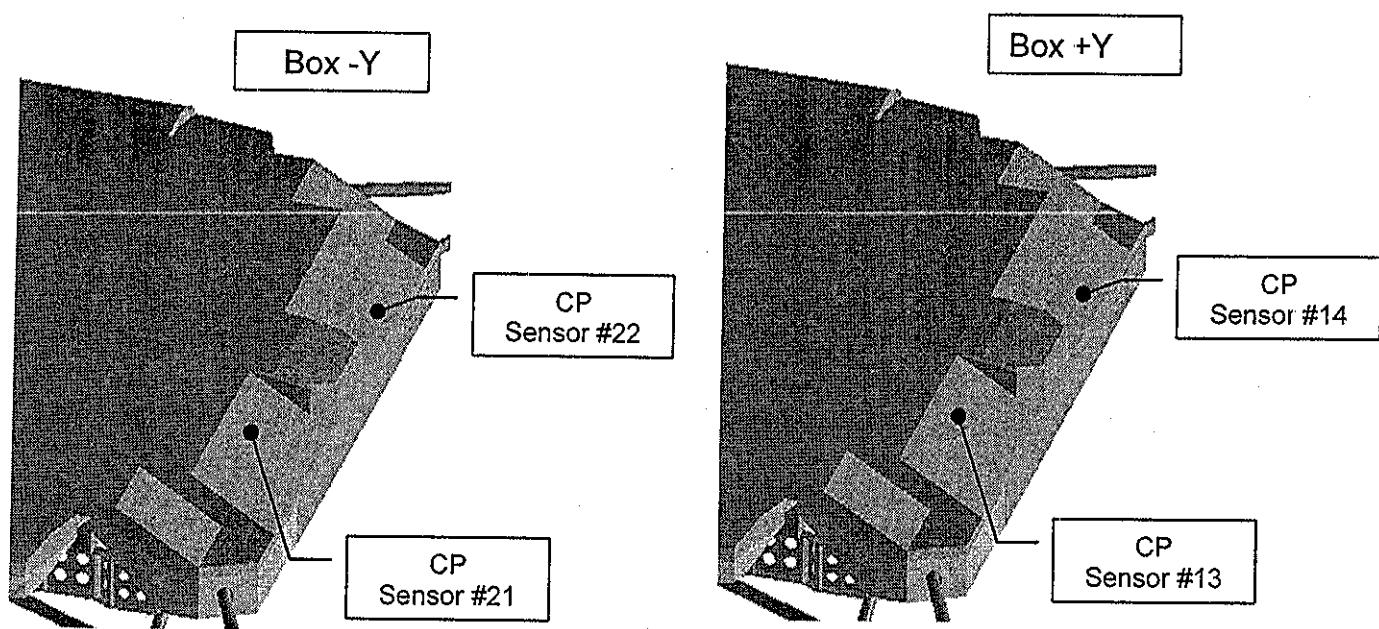


Figure 6-19 CP location on the lateral boxes (+/-Y)

The other 4 CP are located on the side +/-X (see Tab 5-1)  
In the thermal model a node must be present in the location of the chosen CP

### 6.3 FUNCTIONAL TESTS

Functional tests will be run by INFN according to requirements given in ANNEX A. These requirements are provided for reference only

## 7. INSTRUMENTATION AND TEST EQUIPMENT

The complete list of the instrumentation used during the test shall be recorded in Table 7-1  
The list shall be filled up during tests and reported in Test Report.

In addition, a crane is necessary to:

- Move the unit inside the test site to the test facility.
- Lift and position the unit inside the test chamber (2 translational degrees of freedom might be required)
- Remove the unit from the test chamber.

The crane should be compatible with the eventual unit support inside the chamber.





CARLO GAVAZZI SPACE SpA

# RICH SYSTEM

TOF THERMAL TEST PROCEDURE

N° Doc:  
Doc N°:

RICSYS-PR-CGS-009

Ediz.:

3

Issue:

Data:

16/05/2006

Pagina  
Page

25

di  
of

42

## 8. TEST CONDITION

- The UUT shall be tested in its defined configuration: it shall properly closed, all electrical loads shall be present and the UUT interface function(s) shall be simulated

- Unless otherwise specified, all measurements are to be performed at the following ambient condition:

Temperature	+25°C +/- 3°C
Relative Humidity (RH)	30% < RH < 60%
Pressure	Ambient
Cleanliness	100000 class

- All tests, unless otherwise specified, shall be performed by a suitable laboratory in a proper area. General disposition shall be applied to maximize personnel safety from potential hazards.
- Connectors savers shall be used on PFM model as applicable to protect the UUT interface connectors.
- Skilled personnel shall be employed
- All used instruments shall meet the necessary accuracy and shall not degrade the UUT performances.

### 8.1 MEASUREMENTS ACCURACY

Unless otherwise specified, all measurements are to be performed at the following accuracy:

- ñ Tolerance on minimum operative and Non operative temperature -3/0 °C
- ñ Tolerance on maximum operative and Non operative temperature 0/+3 °C
- ñ Temperature will be measured with a absolute uncertainty of ±1 5 °C
- ñ Pressure: -0/+5% of tolerance on max specified value for pressure above  $1.3 \times 10^2$  Pa (1 Torr)  
±25% of tolerance on max specified value for pressure  $1.3 \times 10^{-1}$  to  $1.3 \times 10^2$  Pa  
±80% of tolerance on max specified value for pressure lower than  $1.3 \times 10^{-1}$  Pa (10-3 Torr)



CARLO GAVAZZI SPACE SpA

# RICH SYSTEM

TOF THERMAL TEST PROCEDURE

N° Doc:  
Doc N°:

RICSYS-PR-CGS-009

Ediz.:  
Issue:3 Data:  
Date:

16/05/2006

Pagina  
Page 26 di  
of 42

## 9. TEST PROFILE

The maximum and minimum TRP temperatures (i.e. as measured on the copper shields) are summarized in the following table (see RD 4):

AMS02 TOF Detector	TRP temperature During Tests <sup>1</sup>
MAXIMUM OPERATING	+43°C
MINIMUM OPERATING	-32°C
MAXIMUM NON OPERATING	+50°C
MINIMUM NON OPERATING	-35°C

Table 9-1 Temperatures for TOF

The test is characterized by 4 thermal cycles. During the non-operating phases the Dallas sensors cannot be acquired, therefore the TRP temperature will be monitored via the corresponding PT100.

During the operating phases, In the first characterizing cycle, the chamber shroud will be adjusted in steps until the temperature sensors on the TRP report a temperature equal to the limits presented in Table 9-1

The last cycle will be used for thermal model correlation (TB)

The last part of the test will be used for:

- ii Heaters and thermostats verification
- ii Definition of the minimum environmental temperature that can be experienced by non-operative TOF (with heaters).
- ii Definition of the minimum environmental temperature that allows the TOF switch-ON.

<sup>1</sup> According with Annex B the temperature difference between the PMT Copper Shield and the PMT body is 2°C. The max/min operating temperature of the PMT body are +45°C/-30°C, consequently the max/min operating temperature of the TRP is 2°C lower, namely +43°C/-32°C. These considerations don't apply to the non-operating conditions, when the TRP and the PMT body are isothermal.



CARLO GAVAZZI SPACE SpA

# RICH SYSTEM

## TOF THERMAL TEST PROCEDURE

N° Doc:  
Doc N°:

RICSYS-PR-CGS-009

Ediz.:  
Issue:

3

Data:  
Date: 16/05/2006Pagina  
Page

27

di  
of 42

- |   |                                    |
|---|------------------------------------|
| — test level (TRP)                                  | * stabilization (at least 2 hours) |
| <input type="checkbox"/> functional test            | ▲ unit on                          |
| <input type="radio"/> unit off                      | ◊ enable heaters                   |
| <input checked="" type="checkbox"/> disable heaters |                                    |

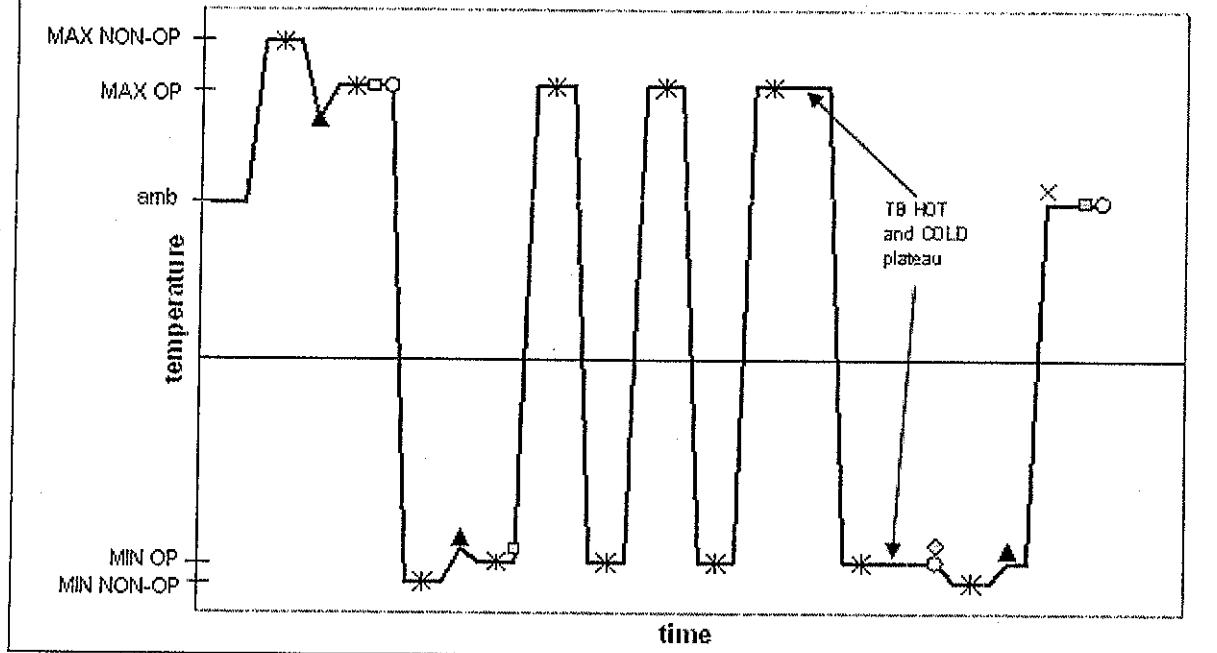


Figure 9-1 Thermal Vacuum Cycling and Thermal Balance Test profile (for the temperature level see Table 8-1)  
Stabilization criteria are provided in the step-by-step procedure.

## 10. TEST SUCCESS CRITERIA

Thermal cycling tests shall be considered successful if the following criteria will be satisfied:

- a. Acquisition of temperatures of TOF in hot/cold stabilized condition (TB test) for sufficient number of relevant points for thermal mathematical model correlation purposes.
- b. Definition of the Maximum/Minimum CP temperature with respect to the maximum/minimum PMT (TRP) allowed temperatures.
- c. Heaters and thermostats nominal operations (in terms of dissipation and duty cycle)
- d. Survival (minimum) temperature definition with heaters enabled.
- e. Minimum switch-on temperature is reached using the heaters
- f. Internal thermal design is performing according to the specification, i.e. the internal heat dissipating sources are well sunk to the TOF body, hence showing small delta-T.

The following goal is under INFN responsibility:

- Absence of degradation or malfunction of TOF during and after exposure to extreme hot and cold environments.

## 11. TEST PROCEDURE VARIATION SHEET

In case that for any reason the test procedure has to be changed, the change shall be described in a Procedure Variation Sheet (PVS) as shown in the next page.

The PVS shall contain:



CARLO GAVAZZI SPACE SpA

# RICH SYSTEM

## TOF THERMAL TEST PROCEDURE

N° Doc: RICSYS-PR-CGS-009  
Doc N°:  
Ediz : 3 Data: 16/05/2006  
Issue:  
Pagina 28 di 42  
Page

- Reference to the test procedure to be changed
- Reference to the relevant test, procedure page and paragraph
- Description of the change, possibly in the form was ... is ...
- Reason for change
- Test Engineer, QA, Test conductor signatures and dates
- Customer signature and date (when required).

Each PVS shall be identified by a reference number provided in sequential order.

All the generated PVS shall be collected in a dedicated section of the Test Report.



CARLO GAVAZZI SPACE SpA

## RICH SYSTEM

TOF THERMAL TEST PROCEDURE

N° Doc:  
Doc N°:

RICSYS-PR-CGS-009

Ediz :  
Issue:

3

Data:  
Date: 16/05/2006Pagina  
Page

29

di  
of

42

## PROCEDURE VARIATION SHEET ref. N°:

Test Procedure Ref.:

Page Revised:

Paragraph Revised:

Description of Change:

Reason for Change:

## CONCURRENCE

Test Cond.	QA	System Eng.		Customer
Date	Date	Date		Date



CARLO GAVAZZI SPACE SpA

# RICH SYSTEM

TOF THERMAL TEST PROCEDURE

N° Doc:  
Doc N°:

RICSYS-PR-CGS-009

Ediz.:  
Issue:

3

Data:  
Date:

16/05/2006

Pagina  
Page

30

di  
of

42

## 12. TEST DATA SHEETS

The step-by-step procedure sheets are provided in the following pages.

### 12.1 DATA SHEETS FILLING UP

The following fields of the data sheets:

- ñ UUT DATA (including Model, Item, C.I., S/N)
- ñ Measured value

shall be filled up during the test performances and shall be part of the Test Report together with photographs, sketches, etc. eventually useful to document the test execution/result.

Remarks field shall be used as a minimum to provide, where appropriate, reference to NCRs and PVS.

Test Report reference data shall be added in the relevant field.

Each data sheet (including the attachments) shall be certified by QA stamp and signature together with the Test Conductor signature and date.

	<b>RICH SYSTEM</b>	N° Doc: Doc N°: Ediz.: Issue:	<b>RICSYS-PR-CGS-009</b>	N° Doc: Doc N°: Ediz.: Issue:
CARLO GAVAZZI SPACE SpA	TOF THERMAL TEST PROCEDURE	3 Date: Pagina Page	16/05/2006 di 42	Ediz.: Date: Pagina Page
		TEST PROCEDURE REFERENCE	TEST REPORT REFERENCE	di of

UUT DATA :	Model	Item	C.I.	S/N
STEP n°	TEST SEQUENCE		EXPECTED VALUE	MEASURED VALUE
<b>Vacuum thermal cycles</b>				
<b>PRELIMINARY OPERATIONS</b>				
0. 1	Record the characteristics of the UUT (S/N, if any)		OK	
0. 2	Take the TOF out of the container		OK	
0. 3	Fix the supports structure to the TOF ring support structure.		OK	
0. 4	Position the TOF on the mounting panel inside the chamber		OK	
0. 5	Connect the electronic cables to the unit and verify harness.		OK	
0. 6	Place the thermal sensors on the TV Chamber according to of Figure 6-18, Figure 6-11, Figure 6-12, Figure 6-13, Figure 6-14, Figure 6-15, Figure 6-16, Figure 6-17 and Table 6-1		OK	
0. 7	Connect the Test Equipment to the cables outside the chamber		OK	
0. 8	Test the flight and test thermal sensors in order to verify the signal		OK	
0. 9	Switch UUT ON at ambient temperature		ON	
0. 10	Perform functional test		OK	
0. 11	Switch UUT OFF Record the ambient temperature and the TRP (with the flight sensor)		OFF	
0. 12	Close the thermal vacuum chamber.		CLOSED	
DATE:	TEST CONDUCTOR	QA	CUSTOMER	

	<b>RICH SYSTEM</b>	N° Doc: Doc N°: Ediz.: Issue:	<b>RICSYS-PR-CGS-009</b>	N° Doc: Doc N°: Ediz.: Issue:
CARLO GAVAZZI SPACE SpA	TOF THERMAL TEST PROCEDURE	3 Pagina Page	16/05/2006 Date: di of	Ediz.: Issue: Pagina Page
		32 di of	42	TEST PROCEDURE REFERENCE

UUT DATA :	Model	Item	C.I.	S/N
STEP n°	TEST SEQUENCE		EXPECTED VALUE	MEASURED VALUE
0. 13	Start data acquisition		START SCAN	
1.0	<b>First thermal cycle</b>			
1. 1	Switch ON the vacuum pump	ON		
1. 2	When chamber pressure is lower than $1 \times 10^{-4}$ hPa, increase the TV chamber temperature in order to reach the maximum non-operating temperature on TRP.		$P < 1 \times 10^{-4}$ hPa	
1. 3	When $DT/DT$ È 3K/h is reached over at least 10 minutes observation time, temperature shall stabilize for at least 2 hours. Record elapsed time and temperature. Record Chamber temperature.		$t > 2$ hr $T_{TRP} = +50^{\circ}\text{C}$ $T_{chamber} =$	
1. 4	Decrease the TV chamber temperature in order to reach $+40^{\circ}\text{C}$ on the TRP	OK	$T_{TRP} = +40^{\circ}\text{C}$	
1. 5	Switch ON the TOF and record the power consumption/dissipation		$T_{TRP} = +40^{\circ}\text{C}$ ON $P_{SPEC}=0.13W$ $P_{PMT}=0.04W$	$P_{TOF}=3.52W$ ( $76PMT+4SFEC$ )
1. 6	Increase gradually the CP temperature until the hottest TRP reports a temperature equal to $+43^{\circ}\text{C}$ (maximum operating temperature)		$T_{TRP}=+43^{\circ}\text{C}$	

DATE:	TEST CONDUCTOR	QA	CUSTOMER
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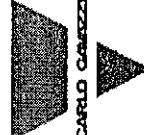
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	<b>RICH SYSTEM</b>	N° Doc: Doc N°: Ediz.: Issue:	<b>RICSYS-PR-CGS-09</b>	N° Doc: Doc N°: Ediz.: Issue:
CARLO GAVAZZI SPACE SpA	TOF THERMAL TEST PROCEDURE	3 Data: Date: Pagina Page	16/05/2006 di 42 of	Ediz.: Issue: Pagina Page
		TEST PROCEDURE REFERENCE	TEST REPORT REFERENCE	di of

UUT DATA :	Model	Item	C.I.	S/N
STEP n°	TEST SEQUENCE			
1. 7	When DT/DX È 3K/h is reached over at least 10 minutes observation time(on the hottest TRP temperature sensor) : Stabilize for at least 2 hours. Record elapsed time and temperature. Record the TRP, CP and TV Chamber shroud temperature. Record the power consumption/dissipation	t> 2 hr $T_{TRP}=+43^{\circ}C$ $P_{SPEC}=0.13W$ $P_{PMT}=0.04W$	$T_{CP-MAXOP}=$ $T_{chamber-MAXOP}=$	$P_{TOF}=3.52W$ (76PMT+4SFEC)
1. 8	Perform functional test (see Annex A)	OK		
1. 9	Switch OFF the TOF	OFF		
1. 10	Decrease the TV chamber temperature in order to reach the minimum non-operating temperature on TRP. When DT/DX È 3K/h is reached over at least 10 minutes observation time(on the coldest TRP temperature sensor) : Stabilize for at least 2 hours. Record elapsed time and temperature. Record the TRP, CP and TV Chamber shroud temperature.	$T_{TRP}=-35^{\circ}C$	$T_{chamber}=$	
1. 11		t> 2 hr $T_{TRP}=-35^{\circ}C$		
1. 12	Increase the CP temperature until the coldest TRP reports a temperature equal to -30°C (minimum switch ON)	OK $T_{TRP}=-30^{\circ}C$		

DATE:	TEST CONDUCTOR	QA
		CUSTOMER

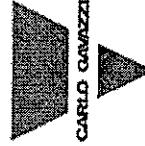
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	<b>RICH SYSTEM</b>	N° Doc: Doc N°: Ediz.: Issue: 3	<b>RICSYS-PR-CGS-009</b>	N° Doc: Doc N°: Ediz.: Issue: 16/05/2006
CARLO GAVAZZI SPACE SPA	TOF THERMAL TEST PROCEDURE	Pagina Page	34	di of
TEST PROCEDURE REFERENCE				TEST REPORT REFERENCE

UUT DATA :	Model	Item	C.I.	S/N	
STEP n°	TEST SEQUENCE		EXPECTED VALUE	MEASURED VALUE	REMARKS
1. 13	Switch ON the TOF and record the power consumption/dissipation		T <sub>TRP</sub> =-30°C ON P <sub>SFEC</sub> =0.13W P <sub>PMT</sub> =0.04W		P <sub>TOF</sub> =3.52W (76PMT+4SFEC)
1. 14	Decrease gradually the CP temperature until the coldest TRP reports a temperature equal to -32°C (minimum operating temperature).		T <sub>TRP</sub> =-32°C		
1. 15	When DT/Dt E 3K/h is reached over at least 10 minutes observation time(on the coldest TRP temperature sensor) : Stabilize for at least 2 hours. Record elapsed time and temperature. Record the TRP, CP and TV Chamber shroud temperature.		t> 2 hr T <sub>TRP</sub> =-32°C P <sub>SFEC</sub> =0.13W P <sub>PMT</sub> =0.04W		T <sub>CP-MINOP</sub> = T <sub>chamber-MINOP</sub> =
1. 16	Perform functional test		OK		
2. 0	<b>Second thermal cycle</b>				
2. 1	Increase the TV chamber temperature in order to reach the maximum operating temperature (see TCP-MAXOP and Tchamber-MAXOP)		OK		

DATE:	TEST CONDUCTOR	QA	CUSTOMER
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# RICH SYSTEM

CARLO GAVAZZI SPACE SpA

TOF THERMAL TEST PROCEDURE

N° Doc: Doc N°: Ediz.: Issue: Pagina Page	<b>RICSYS-PR-CGS-009</b>	N° Doc: Doc N°: Ediz.: Issue: Pagina Page
3 TOF THERMAL TEST PROCEDURE	16/05/2006 di of	3 42 TEST PROCEDURE REFERENCE

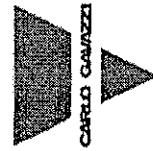
TEST REPORT REFERENCE

UUT DATA :	Model	ITEM		S/N	
STEP n°	TEST SEQUENCE		EXPECTED VALUE	MEASURED VALUE	REMARKS
2. 2	When DT/Dt È 3K/h is reached over at least 10 minutes observation time(on the hottest TRP temperature sensor) ; Stabilize for at least 2 hours. Record elapsed time and temperature. Record the TRP, CP and TV Chamber shroud temperature.		t > 2 hr $T_{TRP} = +43^{\circ}\text{C}$ $P_{SFEC} = 0.13\text{W}$ $P_{PMT} = 0.04\text{W}$	$T_{CP-MAXOP} = T_{chamber-MAXOP} =$	$P_{off} = 3.52\text{W}$ (76PMT+4SFEC)
2. 3	Decrease the TV chamber temperature in order to reach the minimum operating temperature (see TCP-MINOP and Tchamber-MINOP)	OK			
2. 4	When DT/Dt È 3K/h is reached over at least 10 minutes observation time(on the coldest TRP temperature sensor) : Stabilize for at least 2 hours. Record elapsed time and temperature. Record the TRP, CP and TV Chamber shroud temperature.		t > 2 hr $T_{TRP} = -32^{\circ}\text{C}$	$T_{CP-MINOP} = T_{chamber-MINOP} =$	
3.0	<b>Third thermal cycle</b>				
3. 1	Increase the TV chamber temperature in order to reach the maximum operating temperature (see TCP-MAXOP and Tchamber-MAXOP)	OK			
3. 2	When DT/Dt È 3K/h is reached over at least 10 minutes observation time(on the hottest TRP temperature sensor) ; Stabilize for at least 2 hours. Record elapsed time and temperature. Record the TRP, CP and TV Chamber shroud temperature.		t > 2 hr $T_{TRP} = +43^{\circ}\text{C}$ $P_{SFEC} = 0.13\text{W}$ $P_{PMT} = 0.04\text{W}$	$T_{CP-MAXOP} = T_{chamber-MAXOP} =$	$P_{off} = 3.52\text{W}$ (76PMT+4SFEC)
3. 3	Decrease the TV chamber temperature in order to reach the minimum operating temperature (see TCP-MINOP and Tchamber-MINOP)	OK			

DATE: TEST CONDUCTOR

QA

CUSTOMER



# RICH SYSTEM

CARLO GAVAZZI SPACE SpA

TOF THERMAL TEST PROCEDURE

<b>RICH SYSTEM</b>	
Doc N°: Ediz.: Issue:	N° Doc: Doc N°: Ediz.: Issue:
3 Pagina Page	16/05/2006 Data: Date: di of Page

TEST PROCEDURE REFERENCE

UNIT DATA :	Model	TEST PROCEDURE REFERENCE		TEST REPORT REFERENCE	
STEP n°	TEST SEQUENCE		EXPECTED VALUE	MEASURED VALUE	REMARKS
3. 4	When DT/Dt È 3K/h is reached over at least 10 minutes observation time(on the coldest TRP temperature sensor) : Stabilize for at least 2 hours. Record elapsed time and temperature. Record the TRP, CP and TV Chamber shroud temperature.		t> 2 hr T <sub>TRP</sub> =-32°C P <sub>SFEC</sub> =0.13W P <sub>PMT</sub> =0.04W	T <sub>CP-MINOP</sub> = T <sub>chamber-MINOP</sub> =	
4.0	<b>Fourth thermal cycle</b>				
4. 1	Increase the TV chamber temperature in order to reach the maximum operating temperature (see TCP-MAXOP and Tchamber-MAXOP)	OK			
4. 2	When DT/Dt È 0.5K/h is reached (on all the temperature sensor) : Stabilize for at least 5 hours. Record elapsed time and temperature. Record the TRP, CP and TV Chamber shroud temperature.		t> 5 hr T <sub>TRP</sub> =+43°C P <sub>SFEC</sub> =0.13W P <sub>PMT</sub> =0.04W	T <sub>CP-MAXOP</sub> = T <sub>chamber-MAXOP</sub> =	P <sub>TOF</sub> =3.52W (76PMT+4SFEC)
4. 3	Decrease the TV chamber temperature in order to reach the minimum operating temperature (see TCP-MINOP and Tchamber-MINOP)	OK			
4. 4	When DT/Dt È 0.5K/h is reached (on all the temperature sensor) : Stabilize for at least 5 hours. Record elapsed time and temperature. Record the TRP, CP and TV Chamber shroud temperature.		t> 5 hr T <sub>TRP</sub> =-32°C P <sub>SFEC</sub> =0.13W P <sub>PMT</sub> =0.04W	T <sub>CP-MINOP</sub> = T <sub>chamber-MINOP</sub> =	P <sub>TOF</sub> =3.52W (76PMT+4SFEC)
5.0	<b>Heaters test</b>				

DATE:	TEST CONDUCTOR	QA	CUSTOMER
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UUT DATA :		Model	Item	C.I.	
STEP n°	TEST SEQUENCE			EXPECTED VALUE	MEASURED VALUE
5. 1		Switch OFF the TOF and enable the heaters with the minimum flight voltage 113V and decrease gradually the TV-chamber shroud temperature in order to reach the minimum NON operating temperature on the TRP.		UUT OFF Heater ON $T_{TRP} = -35^{\circ}\text{C}$	
5. 2		When $\Delta T / \Delta t = 3\text{K/h}$ is reached over at least 10 minutes observation time(on the coldest TRP temperature sensor) ; Stabilize for at least 2 hours.		$t > 2 \text{ hr}$ $T_{TRP} = -35^{\circ}\text{C}$	
5. 3		Record: TRP , CP and TV Chamber shroud temperature Heaters peak power consumption		$T_{TRP} = -35^{\circ}\text{C}$ $T_{CP} =$ $T_{chamber} =$ $Q_{H\_consump} =$	
5. 4		Increase TV Chamber shroud until the coldest TRP reports a temperature equal to $-30^{\circ}\text{C}$ (minimum switch ON)		$T_{TRP} = -30^{\circ}\text{C}$ $T_{CP} =$ $T_{chamber} =$ $Q_{H\_consump} =$	
5. 5		Switch ON the TOF		UUT ON	
5. 6		Record: TRP , CP and TV Chamber shroud temperature TOF power consumption Heaters peak power consumption		$P_{SFEC} = 0.13\text{W}$ $P_{PMT} = 0.04\text{W}$ $T_{CP} =$ $T_{chamber} =$ $Q_{H\_consump} =$	$P_{TOF} = 3.52\text{W}$ ( $76\text{PMT} + 4\text{SFEC}$ )
5. 7		Increase the temperature and pressure in order to reach ambient temperature and the ambient pressure.	OK		

DATE:	TEST CONDUCTOR	QA	CUSTOMER
-------	----------------	----	----------

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	<b>RICH SYSTEM</b>	N° Doc: Doc N°: Ediz.: Issue:	<b>RICSYS-PR-CGS-009</b>	N° Doc: Doc N°: Ediz.: Issue:
CARLO GAVAZZI SPACE SpA	TOF THERMAL TEST PROCEDURE	3 Pagina Page	16/05/2006 di 42 TEST PROCEDURE REFERENCE	Ediz.: Issue: Pagina Page
				di of TEST REPORT REFERENCE

UUT DATA :	Model	Item	C.I.	S/N
STEP n°	TEST SEQUENCE		EXPECTED VALUE	MEASURED VALUE
5. 8	When the TRP is at +15°C (+/-5°C) disable the heaters		Heaters OFF	
5. 9	When the UUT is at the ambient temperature (+/-5°C) perform the Functional test according to Annex A		OK	
5. 10	Stop data acquisition		STOP SCAN	
5. 11	Open the chamber		OK	
5. 12	Remove test temperature sensors from the UUT		OK	
5. 13	Disconnect the electronic cables		OK	
5. 14	Remove the unit from the TV chamber		OK	
DATE:	TEST CONDUCTOR	QA	CUSTOMER	

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# RICH SYSTEM

## TOF THERMAL TEST PROCEDURE

N° Doc:  
Doc N°:

RICSYS-PR-CGS-009

Ediz.:  
Issue:

3

Data:  
Date:

10/05/2006

Pagina  
Page

39

di  
of

42

### 13. ANNEX A: FUNCTIONAL TEST (FOR INFN USE ONLY)

Functional tests will be run according to TOF group requirements.

**Purpose of the functional test** is to have a fast outlook of the behaviour of scintillation counters, PMT and on-detector electronics. All PMT of the TOF will be set at a standard HV of 1950 Volt. All the 4 front-end SFEC cards will be powered and connected to a DAQ system to readout the individual PMT dynode signal. The anode signals of one central counter of plane X and one of plane Y will be monitored and processed by a 4 channels digital scope to generate a trigger signal at the passage of cosmic rays and the SFEC DAQ system will register the dynode signals of the interested counters. The expected rate of cosmic rays being 2 Hz a 1-2 hours run should be sufficient to test the mean value and the rms for all PMT. In this way the mean pulse heights should be controlled with a few thousand events per counter at the 5 % level.

**Cable connections** of the TOF to the Thermo-Vacuum Chamber Flange has been already defined with the operating staff in Terni. It is shown schematically in Figure 13-1.

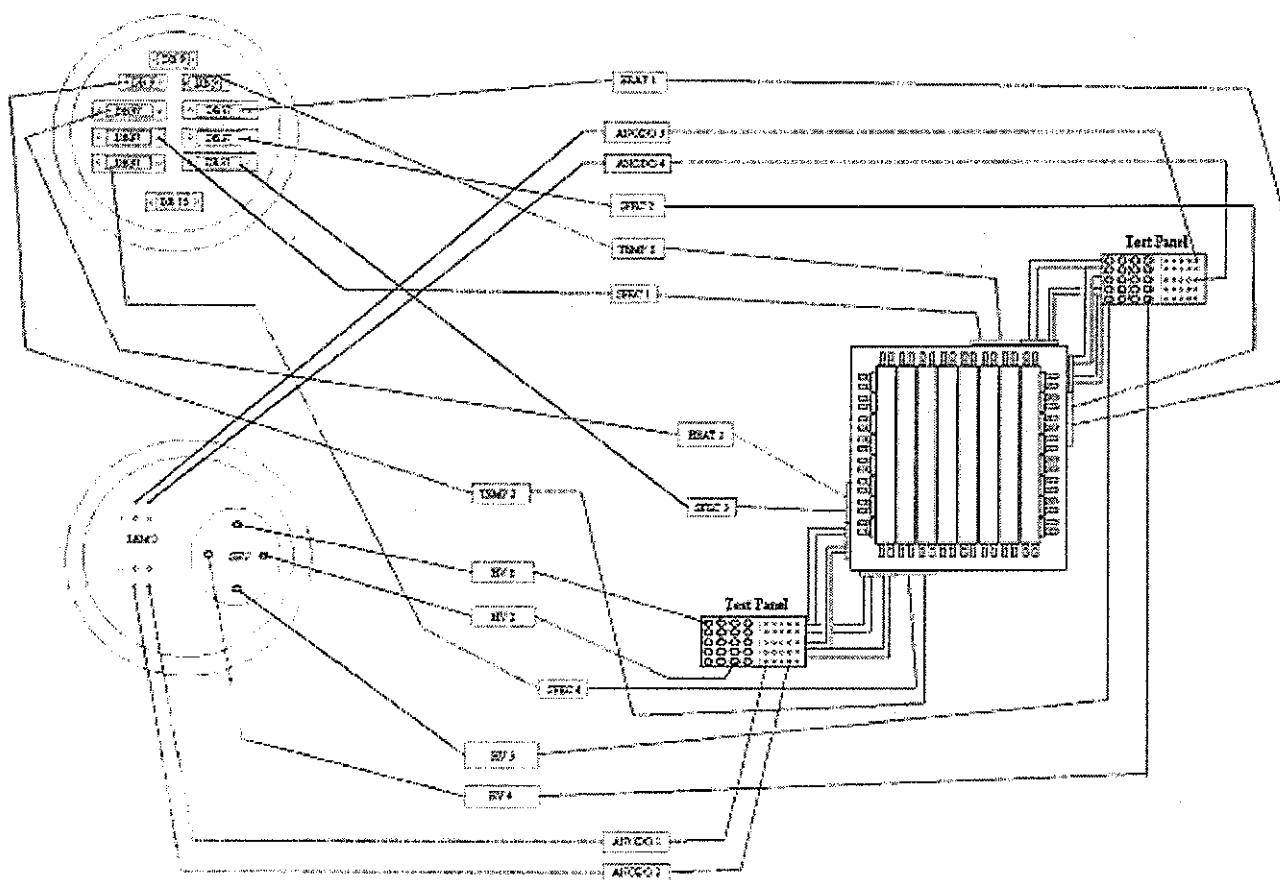


Figure 13-1 TV Chamber Flange Cabling

The set-up for the Functional Test (FT) consists in :

1. Commercial PMT High Voltage power supply with four channels capable of 1mA at 2000 V, with current limiter and short circuit protection
2. Commercial low voltage power supply + 3.3 V 150 W
3. Commercial 4 channels Digital Scope with logic functions built in
4. Custom DAQ card with PC interface
5. Dallas sensors custom reading card with a PC interface
6. Commercial Portable PC for data storage and analysis



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## TOF THERMAL TEST PROCEDURE

N° Doc:

RICSYS-PR-CGS-009

Doc N°:

10/05/2006

Ediz :

3

Issue:

Data:

Pagina

40

Page

di

42

A sketch of the Functional Test Setup is shown in Figure 13-2.

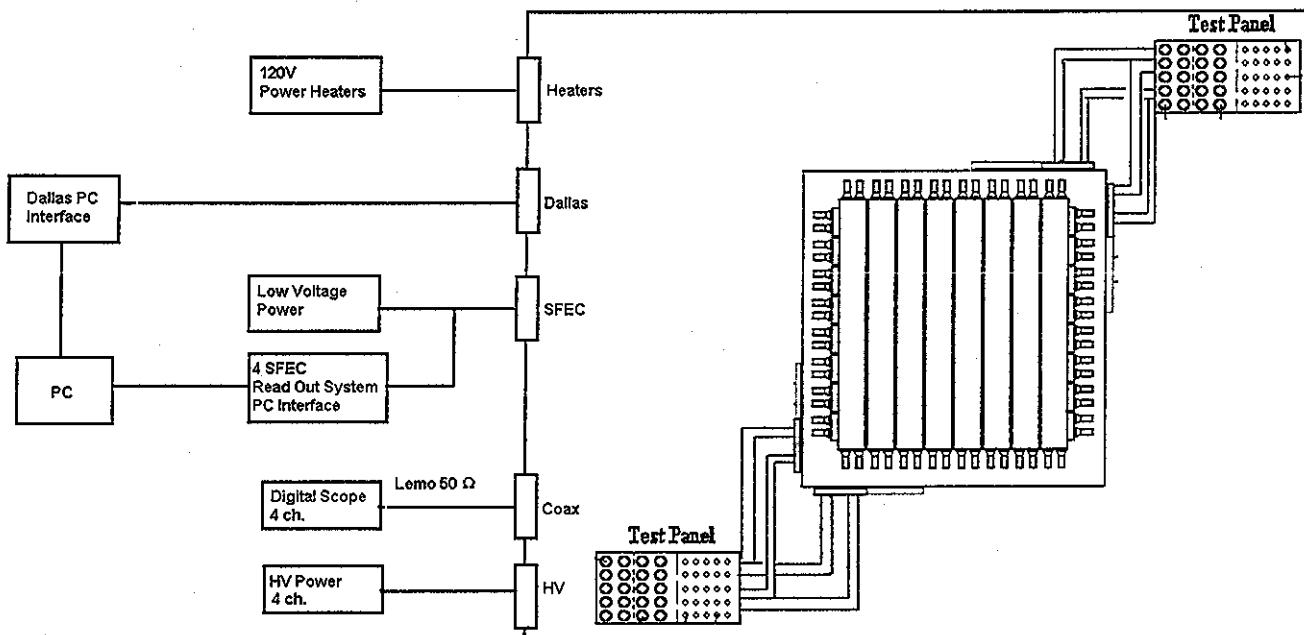


Figure 13-2 Functional Test Setup

### Functional Test Procedure

Let  $T = 0$  be the starting time of the FT, the following is a time schedule of the functional test.

1.  $T = 0$  Power up of the PMT and of the front-end electronics
2. 1 m Control of the HV Supply power dissipation OK
3. 5 m Visual inspection of Scope anode signals and trigger OK
4. 15 m Dynode spectra scan for anomalies OK
5. 30 m Dallas sensor readout and start of data acquisition run OK
6. 2 h End of data acquisition run and start of off-line analysis

The numbered run data file will be copied in data storage and will undergo a preliminary off-line analysis in about two hours. OK

The length of the data-taking run can be variable according to the thermo-vacuum conditions and the thermal cycles program. Each OK means that suitable actions (not described here) will be taken in case of failures



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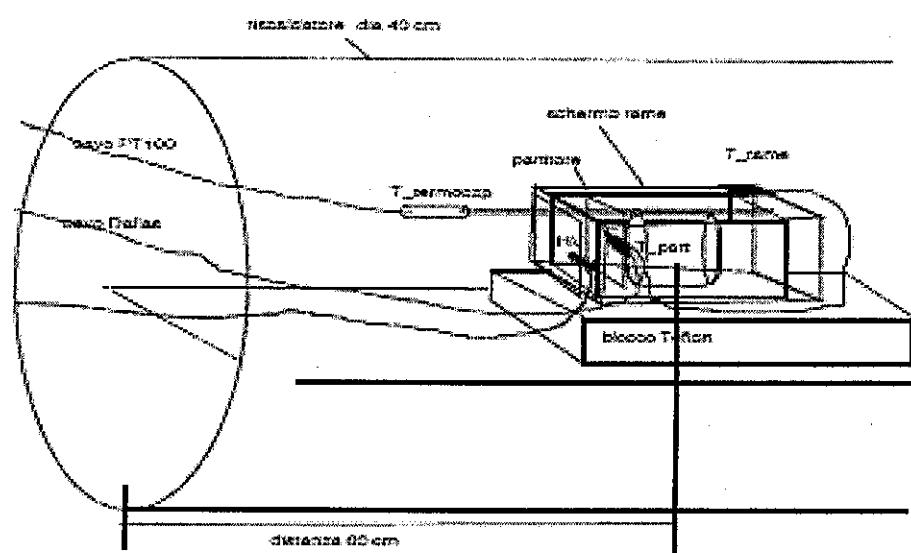
## TOF THERMAL TEST PROCEDURE

N° Doc: RICSYS-PR-CGS-009  
Doc N°:  
Ediz.: 3 Data: 10/05/2006  
Issue:  
Pagina 41 di 42  
Page

### 14. ANNEX B: PMT + COPPER SHIELD TV-TEST

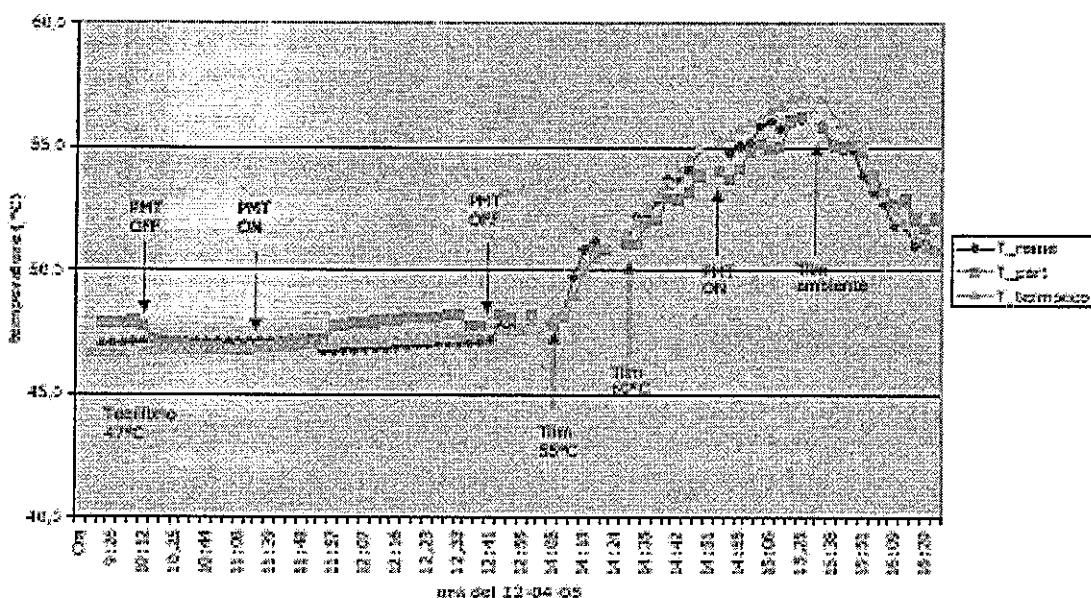
From Prof. Palmonari received 12/04/06

Set-up test TVT di un PMT con schermo di rame



Questo è il run di oggi. Siamo partiti da una situazione stabile tutta la notte.

Termica PMT + schermo rame





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N° Doc:  
Doc N°:

RICSYS-PR-CGS-009

Ediz :  
Issue:

3

Data:  
Date: 10/05/2006Pagina  
Page

42

di  
of 42

## 15. ANNEX C: TEMPERATURE LEVEL DEFINITION

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Via Gallarate 150  
20151 MILANO  
FAX: 02 3086458

Att.ne: Sig. Massimiliano Olivier

Olivier  
VERTOLE  
TOLWA

Facendo seguito alla teleconferenza tenutasi in data odierna con Carlo Gavazzi Space e il Thermal Working Group della AMS-02 Collaboration, vi confermiamo che per ridurre l'aging dei PMT del detector TOF, effetto direttamente proporzionale alla temperatura degli PMT stessi, è necessario contenere il valore della temperatura massima operativa e non operativa del test.

Nella seguente tabella sono pertanto definiti i valori di temperatura che dovranno essere utilizzati durante il Test di termovuoto del TOF:

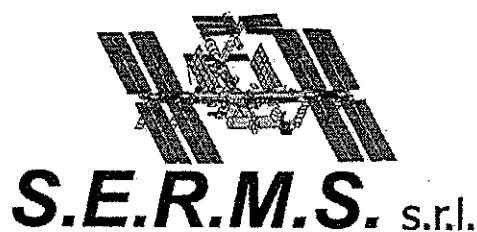
AMS-02 TOF Detector	PMT temperature during test
MAXIMUM OPERATING	+ 45 °C
MINIMUM OPERATING	- 30 °C
MAXIMUM NON OPERATING	+ 50 °C
MINIMUM NON OPERATING	- 35 °C

Preghiamo pertanto CCS di inserire tali valori all'interno della nuova issue della procedura di test.

Con i migliori saluti

Federico Palmonari  
Responsabile INFN del TOF Detector, Bologna

Bologna, 5 Aprile 2006

**TECHNICAL REPORT**

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Date: 28<sup>th</sup> February 2006

**Laboratory for the study of radiation effect on space materials**  
Via Pentima Bassa 21 Terni - 05100 TR - phone/fax: +39.0744 49 29 13

Reference	Content
Thermo-Vacuum Chamber (TVC)	Description of the chamber, flanges, feedthrough and equipment

*signature*

prepared by :	<u>28/02/06</u> <i>Ing. Serena Borsini</i> <u>data</u>
controlled by:	<u>28/02/06</u> <i>Ing. Borsini Serena</i> <u>data</u>
approved by:	<u>28/02/06</u> _____ <u>data</u>

**change record**

date	change description	revision
20/12/05	First emission	A01
18/01/06	Description of connectors-vacuum side	A02
28/02/06	Description of the chamber performance and available equipment	A03

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# TECHNICAL REPORT

doc: TVC\_Technical Report  
data: 20/12/05  
rev: A03  
pag: 2 di 25  
file: TVC\_Technical Report\_A03

## INDEX

<b>INTRODUCTION</b>	2
<b>DESCRIPTION OF THE THERMO-VACUUM CHAMBER</b>	3
DIMENSION OF THE CHAMBER AND TECHNICAL DATA	3
<b>DESCRIPTION OF THE DATA CHAMBER</b>	5
<b>DESCRIPTION OF CHAMBER PERFORMANCE</b>	7
TESTS DONE DURING THE TRIAL PHASE	7
CHECK OF COLD PLATE TEMPERATURE UNIFORMITY	11
<b>DESCRIPTION OF THE AVAILABLE CONNECTORS</b>	21
<b>DESCRIPTION OF THE AVAILABLE EQUIPMENT</b>	23
HEATERS	23
STRAIN GAUGES	24
TEMPERATURE SENSORS (PT100)	25
TEMPERATURE CONTROLLER	25
CHO-TERM - THERMALLY CONDUCTIVE ELASTOMER INSULATOR	25

## INTRODUCTION

Aim of this report is to give some technical information about the thermo vacuum chamber of SERMS laboratory, flanges, feedthrough and the equipment available at the moment. The chamber was certified by the supplier (Angelantoni Industrie SpA) and is ready to be used.

The information included in this document can be used to design and schedule thermo-vacuum tests and the related data acquisition using PT100 sensors, strain gauges, heaters, etc.

# TECHNICAL REPORT

doc TVC\_Technical Report  
data: 20/12/05  
rev: A03  
pag 3 di 25  
file: TVC\_Technical Report\_A03

## DESCRIPTION OF THE THERMO-VACUUM CHAMBER

### *Dimension of the TV Chamber and technical data*

- Diameter of the inner cylinder (shroud): 2.100 mm;
- Length of the cylinder: 2.100 mm;
- Minimum pressure:  $5 \times 10^{-5}$  mbar (nominal value); registered value during commissioning (chamber without any test item inside):  $3 \times 10^{-7}$  mbar;
- Sliding door with three plates (cold plates) fixed on the inner side furnished of M5 holes to fix the test item;
- Dimension of the cold plates:
  - Lower cold plate mm 500 x 1820
  - Middle cold plate mm 500 x 1970
  - Upper cold plate mm 500 x 1550
- Temperature range for the shroud: -70 ÷ +125 °C;
- Temperature range for the cold plates: -70 ÷ +125 °C;
- Average temperature gradient 1°C/min (in the range -20 ÷ +50 °C for the cold plates and in all the range for the shroud).

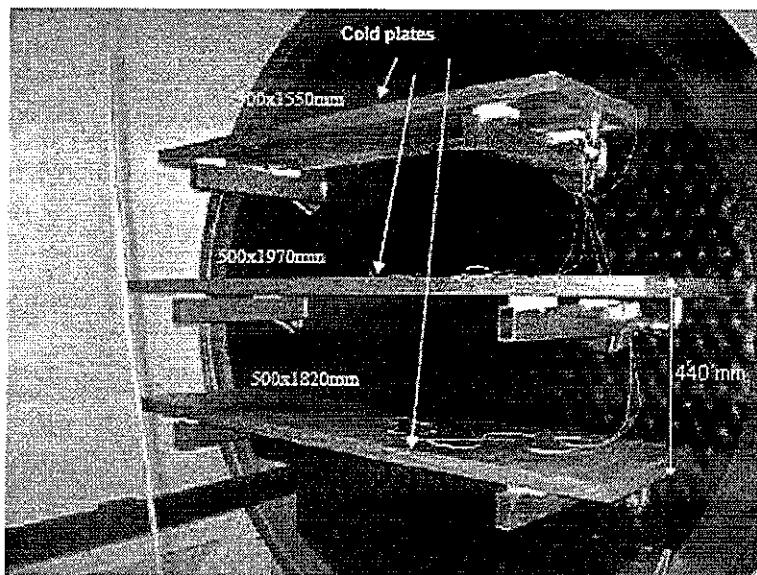


Figure 1 – Dimensions of cold plates.

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# TECHNICAL REPORT

doc TVC\_Technical Report

data: 20/12/05

rev: A03

pag 4 di 25

file: TVC\_Technical Report\_A03

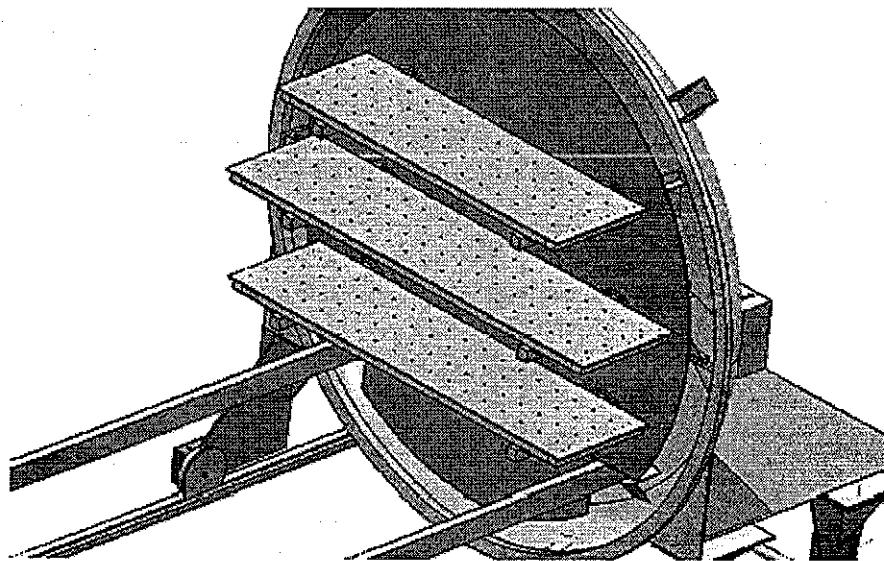


Figure 2 – M5 holes on cold plates.

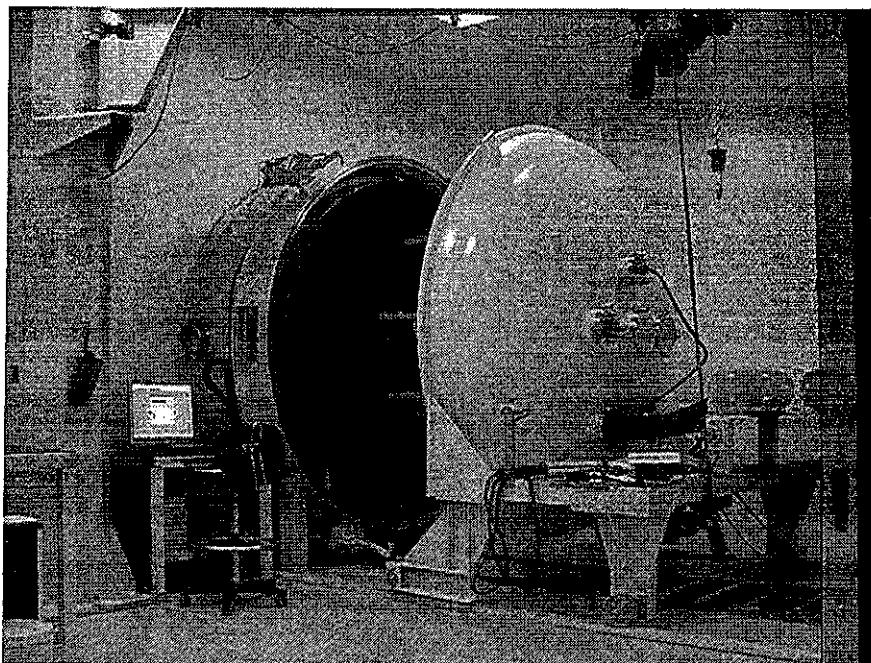


Figure 3 – Thermo-Vacuum Chamber.

# TECHNICAL REPORT

doc TVC\_Technical Report  
data: 20/12/05  
rev: A03  
pag 5 di 25  
file: TVC\_Technical Report\_A03

## DESCRIPTION OF THE DATA CHAMBER

The software used to monitor the chamber is able to acquire up to 22 parameters (see Figure 4). Through these signals the set of the chamber can be evaluated and monitored. The temperature sensors of the camera acquire signal every 5 seconds.

During a test, additional test temperature sensors (64 at maximum) can be used to control and monitor the temperature variation of the test item. These sensors can be acquired using a National Instrument data acquisition system.

Pannello 1 monitoraggio misure			
00 - T Fluido Intim. Cold Plate °C	15.0	16 - Pt100 3 °C	16.2
01 - T Fluido Intim. Shroud °C	17.1	17 - Pt100 4 °C	16.1
02 - T Media reg. Cold Plate °C	16.2	18 - Pt100 5 °C	15.9
03 - Pt100 Temperatura reg. Shroud °C	16.0	19 - B.S: P aspirazione Bar	8.0
04 - T reg. Pt100 Cold Plate 1 °C	16.1	20 - B.S: P mandata Bar	12.7
05 - T reg. Pt100 Cold Plate 2 °C	16.2	21 - A.S: P aspirazione Bar	8.0
06 - T reg. Pt100 Cold Plate 3 °C	16.1	22 - A.S: P mandata Bar	9.5
07 - T acq. Pt100 Cold Plate 1 °C	16.1	23 - Non usato	0.0
08 - T acq. Pt100 Cold Plate 2 °C	16.1	24 - Non usato	0.0
09 - T acq. Pt100 Cold Plate 3 °C	15.9	25 - Non usato	0.0
10 - Pressione Camera mBar	9.72E+2	26 - Non usato	0.0
11 - T Cryo 2 °K	288.2	27 - Non usato	0.0
12 - T Cryo 1 °K	290.1	28 - Non usato	0.0
13 - P Pirani Cryo mBar	7.99E+1	29 - Non usato	0.0
14 - Pt100 1 °C	16.0	30 - Non usato	0.0
15 - Pt100 2 °C	16.2	31 - Non usato	0.0

Figure 4 – Parameters used to monitor the chamber.

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## TECHNICAL REPORT

doc. TVC\_Technical Report

data: 20/12/05

rev: A03

pag. 6 di 25

file: TVC\_Technical Report\_A03

The acquired data can be reported in a graph as a function of the time..

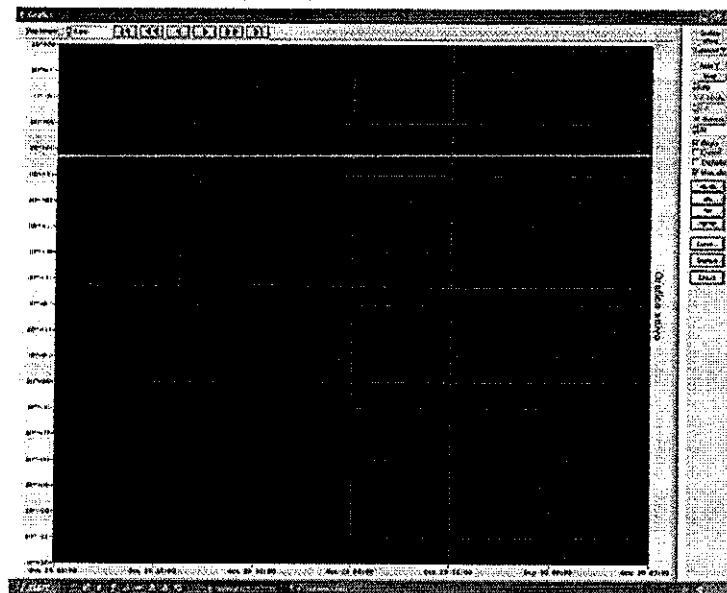


Figure 5 – Pressure of the chamber vs. time.

Using cursor on the graph, the temperature and pressure gradient can be evaluated.

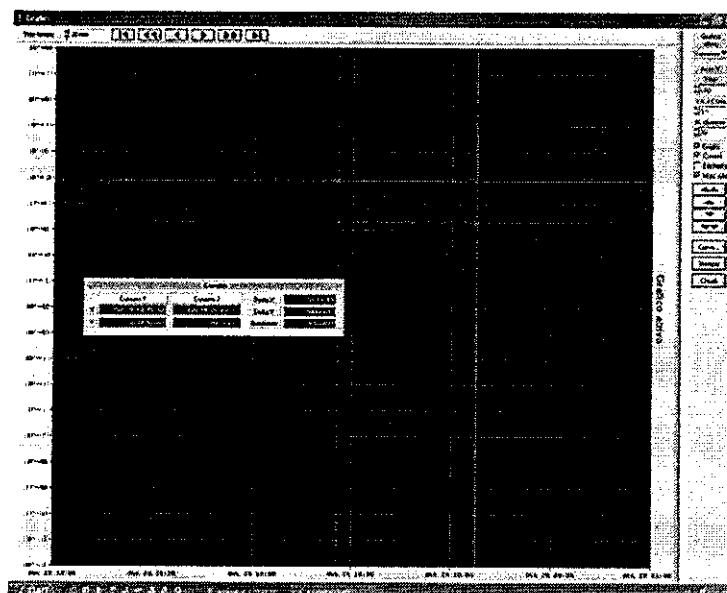


Figure 6 – Cursor to evaluate temperature and pressure gradient.

All the registered data can be converted in ASCII format.

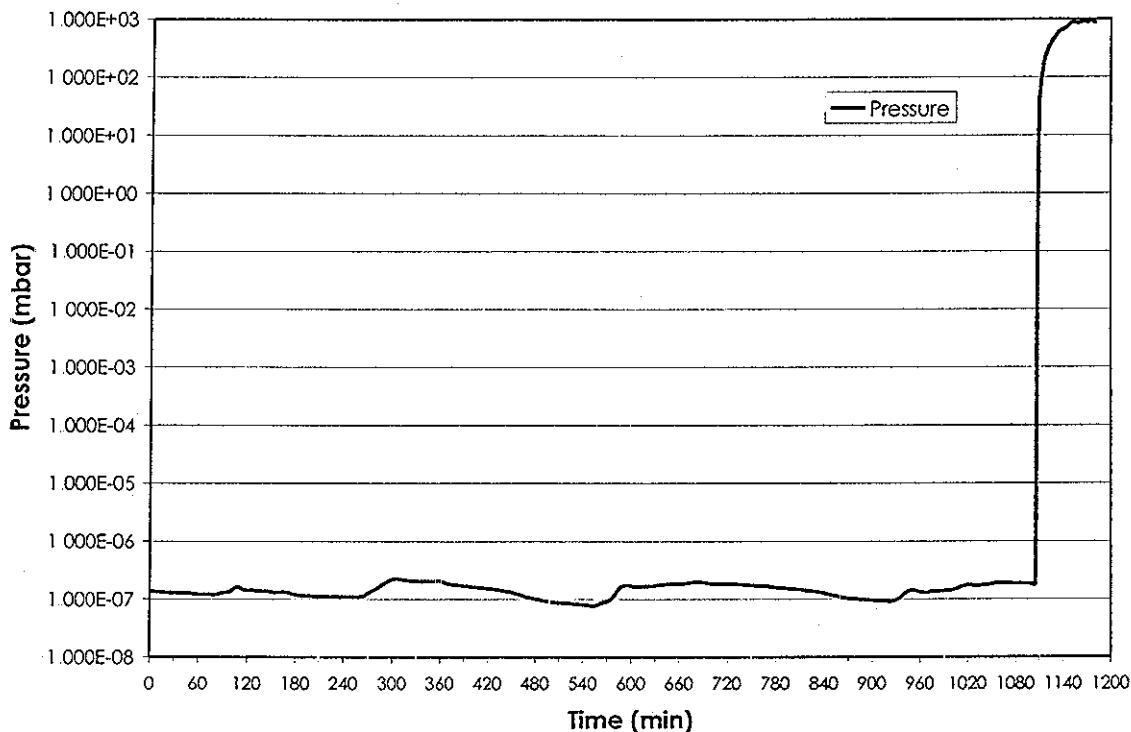
## DESCRIPTION OF CHAMBER PERFORMANCE

### ***Test done during the trial phase***

In this section the graphs and data obtained during the trial phase are reported. During this phase all the function and performance of the chamber were tested: pressure range and the temperature range of cold plate and shroud.

Six temperature sensors (PT100) were placed on the shroud in order to monitor all the surface uniformly and three PT100 were placed on the cold plates (one each CP).

The acquisition rate of sensors (both temperature and pressure) was set to 5 sec.



**Figure 7 – Pressure profile of the chamber.**

In Fig 7 the pressure profile of the TVC is showed. The pressure is very stable during the time (over a total period of about 16 hours) fluctuating between a maximum value of  $1.9 \cdot 10^{-7}$  mbar and a minimum

# TECHNICAL REPORT

doc TVC\_Technical Report

data: 20/12/05

rev: A03

pag: 8 di 25

file: TVC\_Technical Report\_A03

value of  $7.7 \cdot 10^{-8}$ . According to this profile, the pressure of the chamber achieves the ambient value in about 75 minutes.

The temperature range of the shroud ( $-70^{\circ}\text{C} \div +125^{\circ}\text{C}$ ) was tested (see Figure 8) both with cold plates control switched on and off.

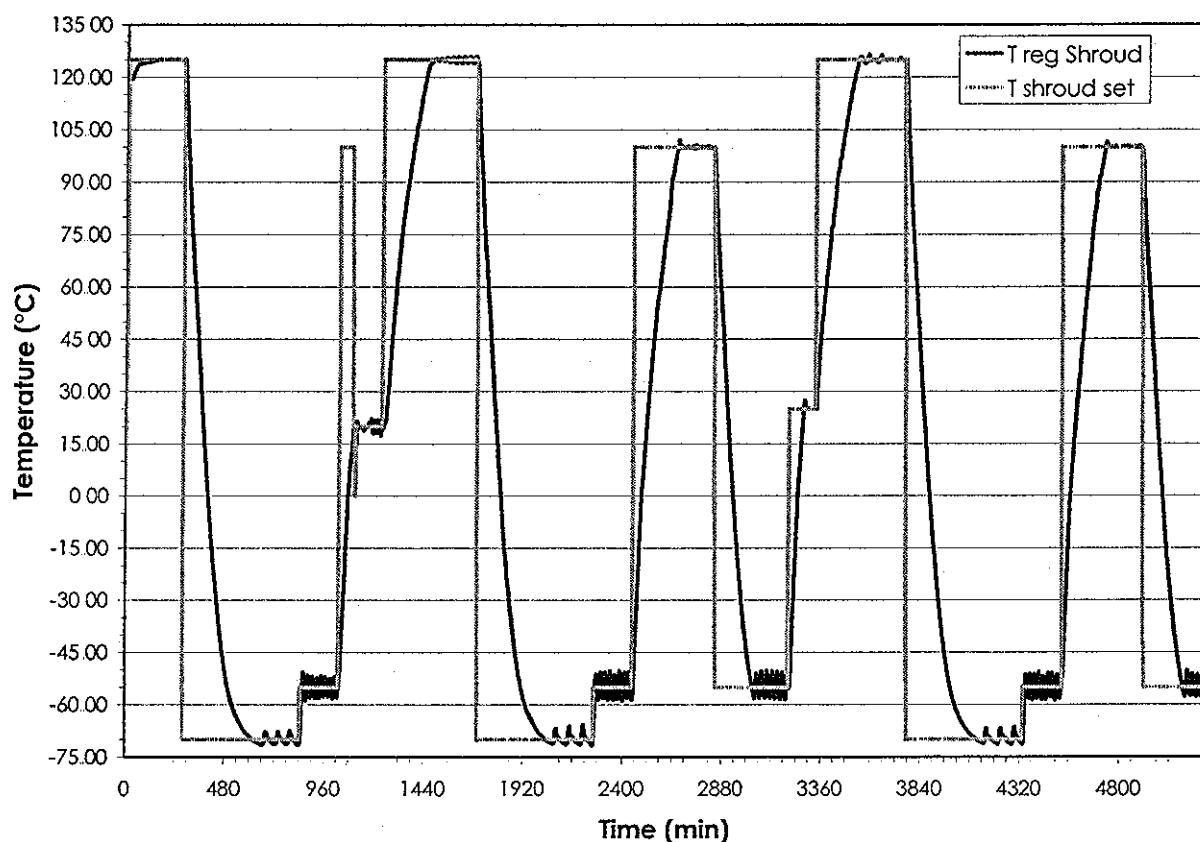


Figure 8 – Temperature range of shroud with cold plate control switched off.

To check the cold plates temperature range and the temperature gradient of the chamber, only the cold plate control was powered on. The temperature profile was set out between  $-20^{\circ}\text{C}$  and  $+50^{\circ}\text{C}$ . After two cycles, the shroud control was powered on. The temperature profile of the shroud followed the same profile of cold plate (see Figure 9).

# TECHNICAL REPORT

doc TVC\_Technical Report

data: 20/12/05

rev: A03

pag: 9 di 25

file: TVC\_Technical Report\_A03

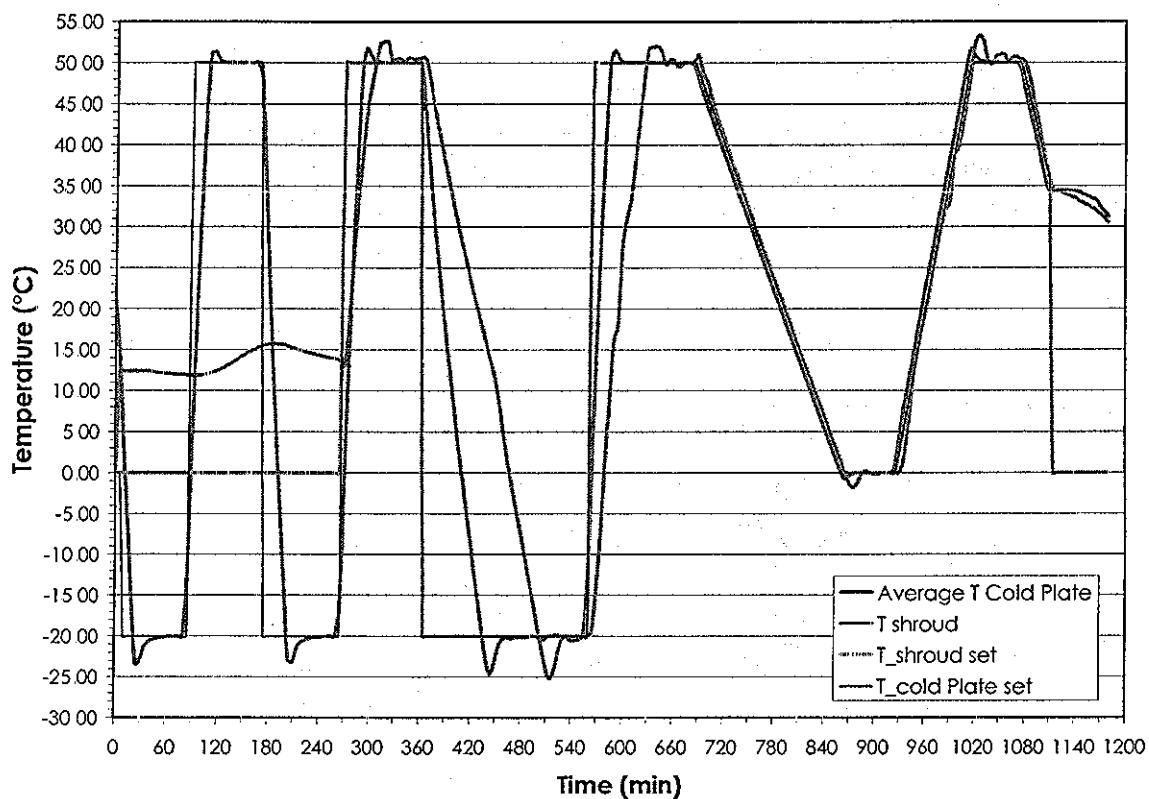


Figure 9 – Temperature profile of cold plates and shroud during the test.

As reported in the Figure 10, the temperature gradient of cold plate, with shroud control switched off, both in cooling and heating is about 2°C/min. With the shroud control switched on, the temperature gradient of cold plate is about 1°C/min in cooling and 2°C/min in heating. The difference is due to the cooling power of the chamber, smaller than the heating power.

Due to this difference, as reported in the Figure 11, the temperature gradient of shroud, with cold plates control switched on, is about 0.5°C/min in cooling and 1°C/min in heating.

# TECHNICAL REPORT

doc TVC\_Technical Report

data: 20/12/05

rev: A03

pag: 10 di 25

file: TVC\_Technical Report\_A03

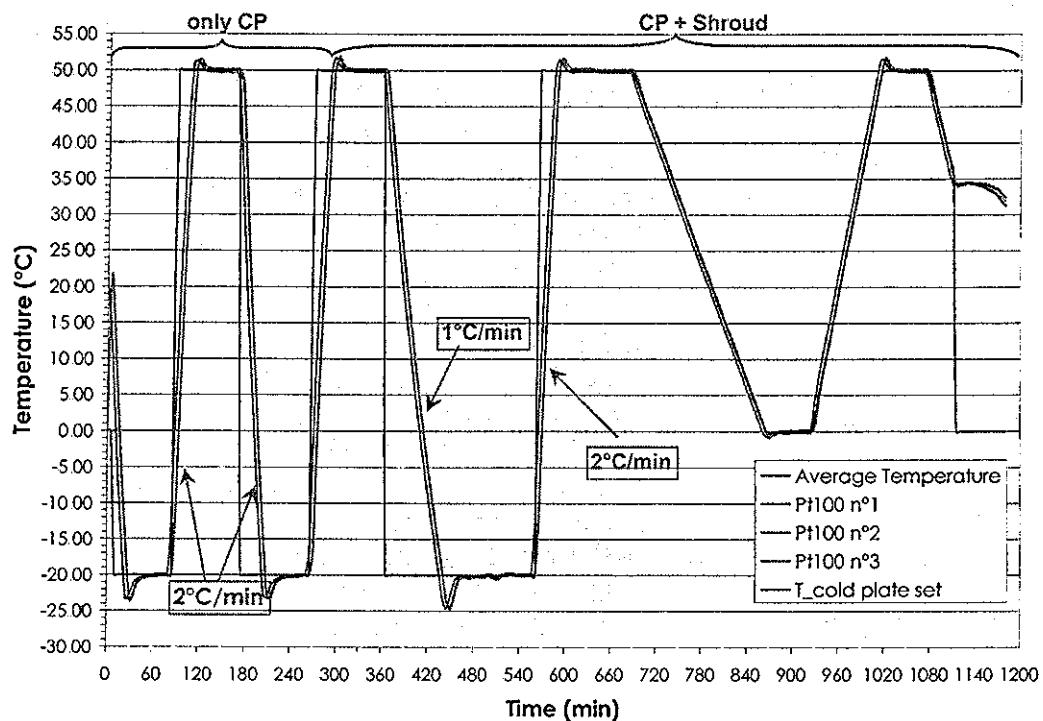


Figure 10 – Temperature profile and gradient of cold plate both without and with shroud control powered on.

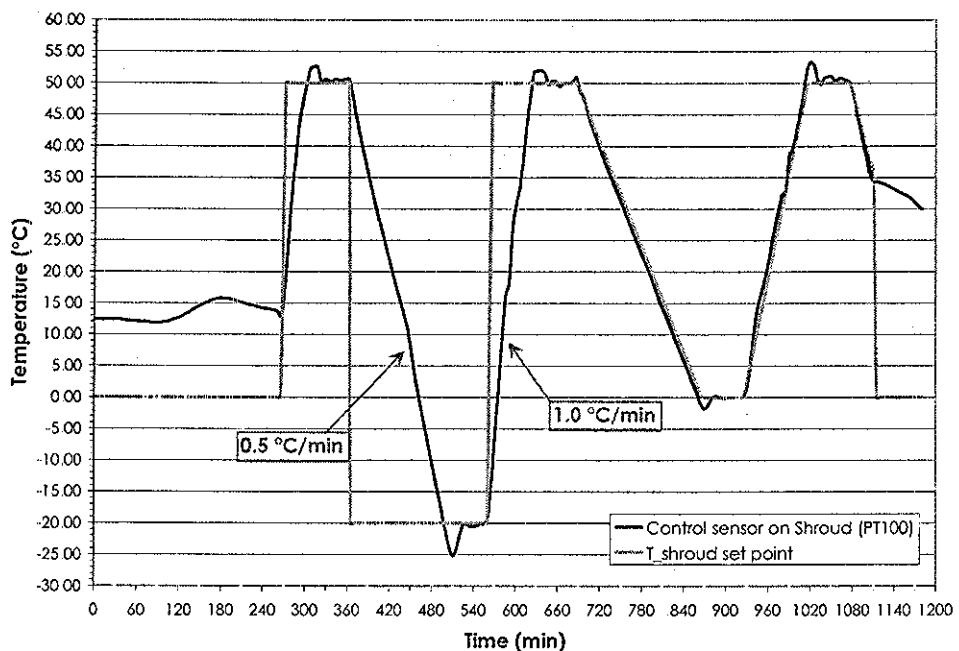


Figure 11 – Temperature profile and gradient of shroud.

***Check of cold plate temperature uniformity***

To check the distribution of the temperature along a cold plate, additional tests were performed. Three PT100 sensors were placed on each cold plate as showed in Figure 12.

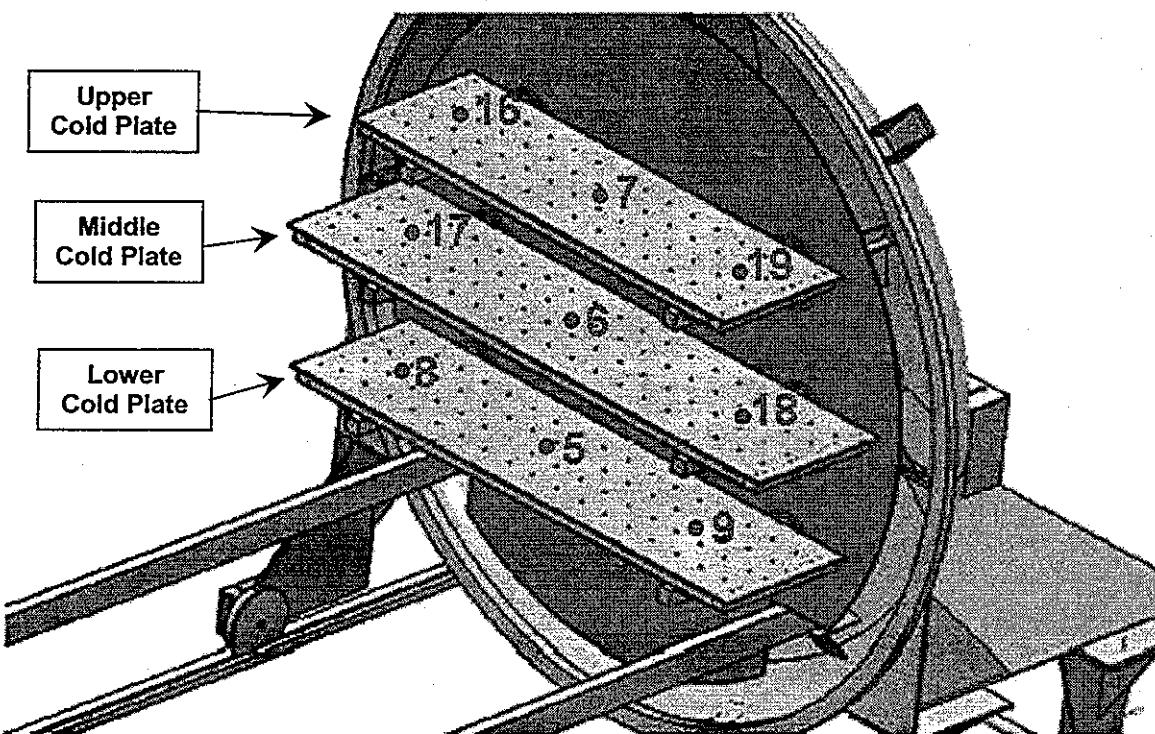


Figure 12 – PT100 sensors placed on cold plates.

The maximum temperature gradient for each cold plate was calculated.

The profile chosen is the AMS-electronics temperature profile for thermo-vacuum test (temperature range between -50°C and +90°C). Once the temperature reach the set point, then it stabilized for 5 hours. During the test, shroud control was switched on. Shroud temperature followed the cold plate temperature profile.

In the next figures the temperature profile and the maximum gradient for lower, middle and upper cold plate are showed.

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# TECHNICAL REPORT

doc. TVC\_Technical Report

data: 20/12/05

rev: A03

pag. 12 di 25

file: TVC\_Technical Report\_A03

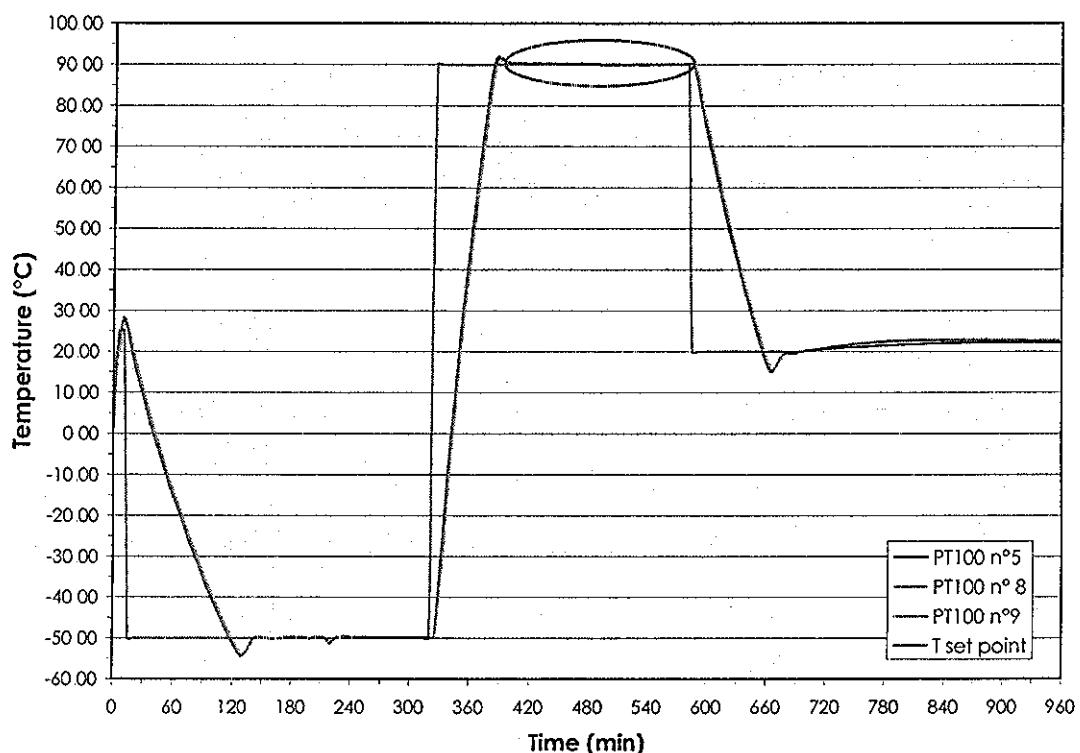


Figure 13 – Temperature profile of lower cold plate (the lightered zone is enlarged in figure 14).

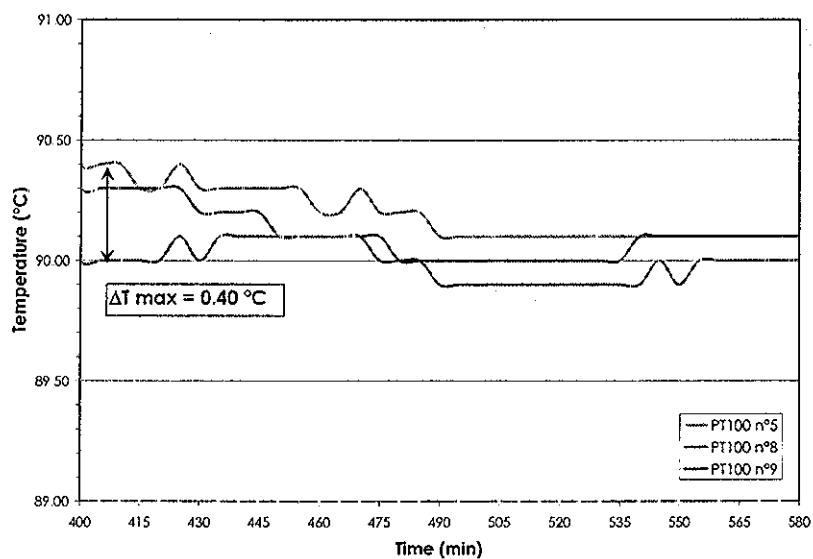


Figure 14 – Maximum temperature gradient for lower cold plate.

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# TECHNICAL REPORT

doc TVC\_Technical Report

data: 20/12/05

rev: A03

pag: 13 di 25

file: TVC\_Technical Report\_A03

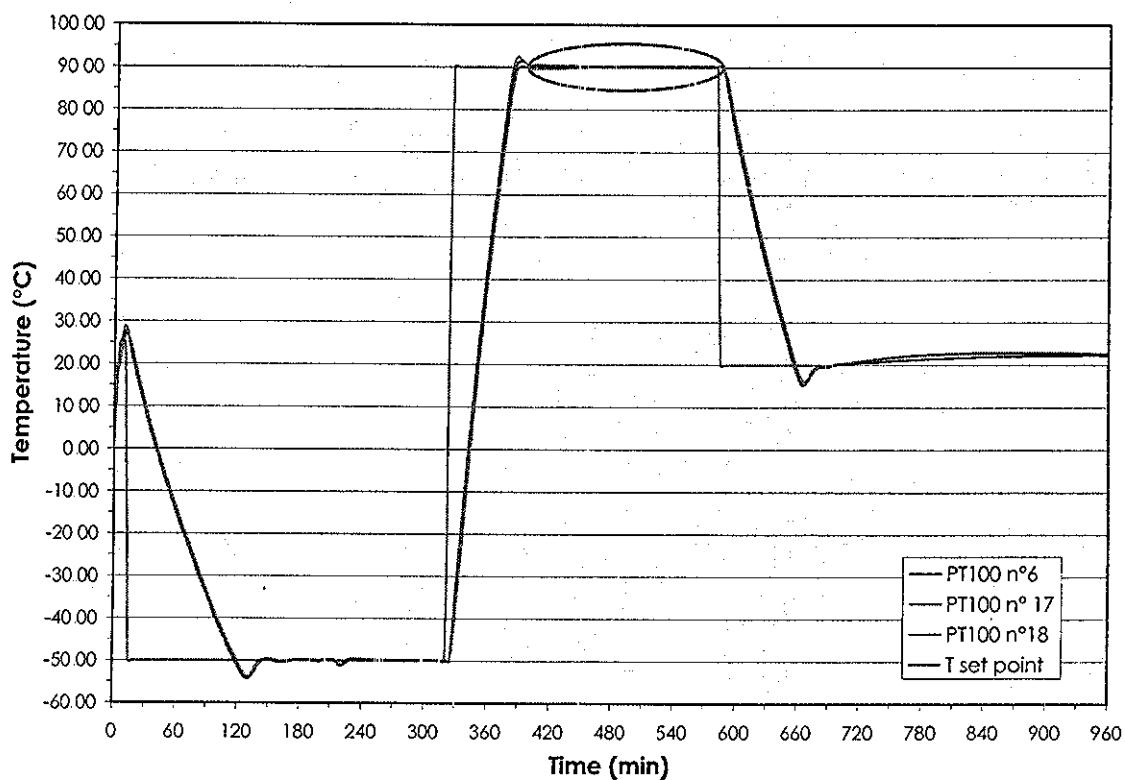


Figure 15 – Temperature profile for middle cold plate (the lightered zone is enlarged in the figure 16).

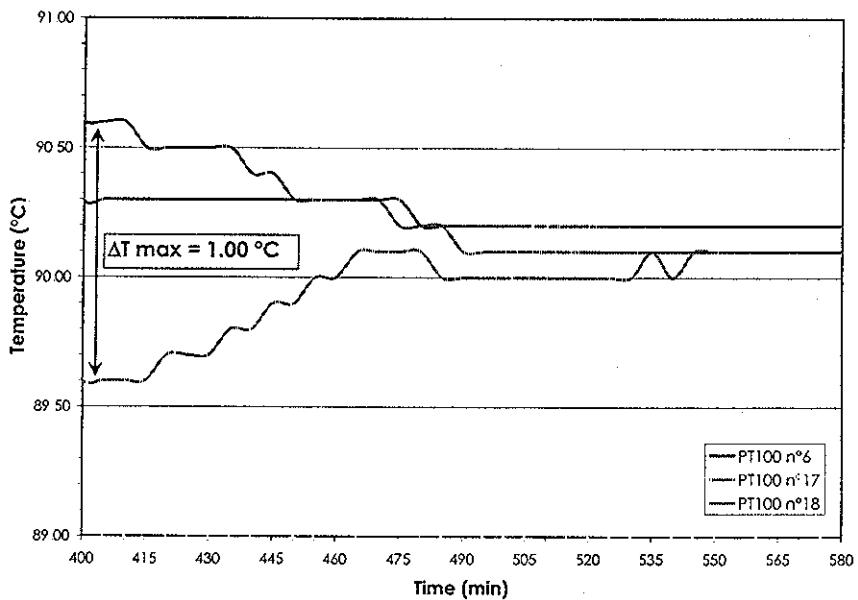


Figure 16 – Maximum temperature gradient for middle cold plate.

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# TECHNICAL REPORT

doc TVC\_Technical Report

data: 20/12/05

rev: A03

pag: 14 di 25

file: TVC\_Technical Report\_A03

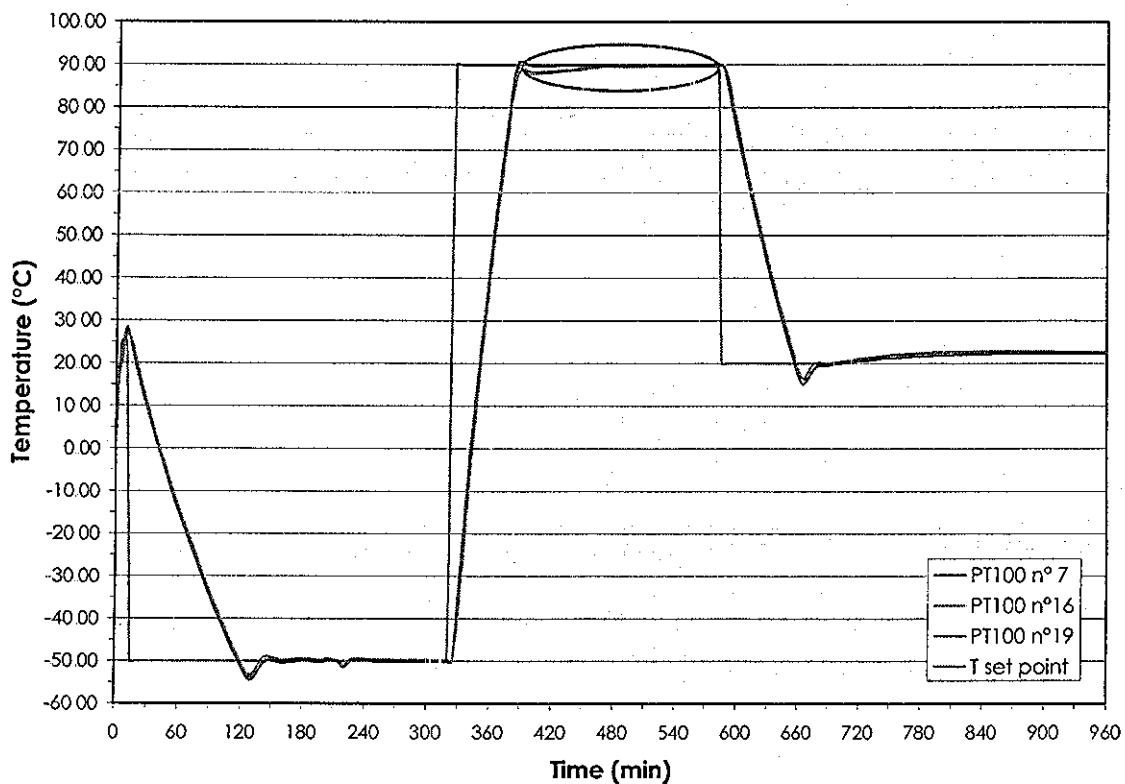


Figure 17 – Temperature profile for upper cold plate (the lightered zone is enlarged in figure 18).

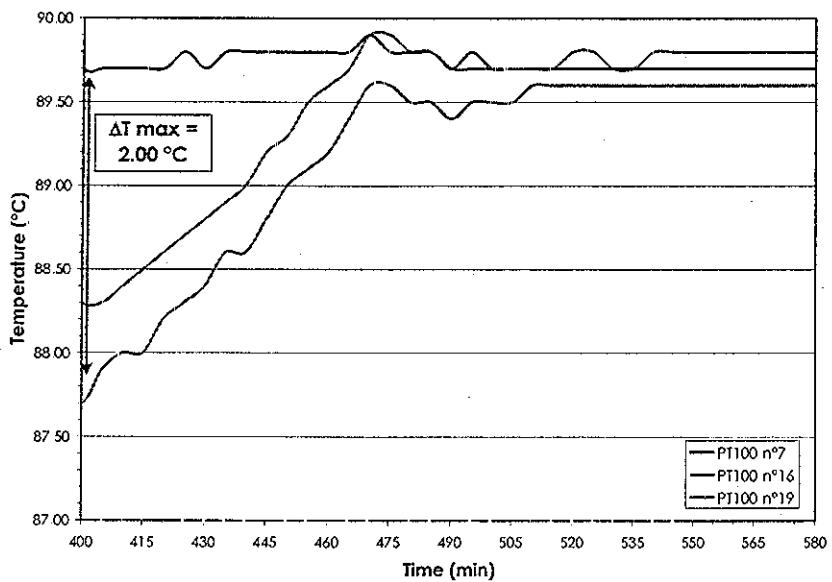


Figure 18 – Maximum temperature gradient for upper cold plate.

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**TECHNICAL  
REPORT**

doc TVC\_Technical Report  
data: 20/12/05  
rev: A03  
pag. 15 di 25  
file: TVC\_Technical Report\_A03

The maximum temperature gradient is higher for middle and upper rather than lower cold plate. It is larger during the first phase of stabilization; after one hour it goes down to 0.20°C for all cold plates.

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# TECHNICAL REPORT

doc TVC\_Technical Report  
data: 20/12/05  
rev: A03  
pag. 16 di 25  
file: TVC\_Technical Report\_A03

## DESCRIPTION OF THE AVAILABLE FLANGES

At the SERMS laboratory there are three ISOK flanges available at the moment; all the flanges are made of stainless steel (AISI 304) having a nominal diameter of 200mm and 12mm thickness. Holes have been realized on these flanges to mount SUB-D feedthrough (MIL-C-24308) as it is illustrated in the next figures.

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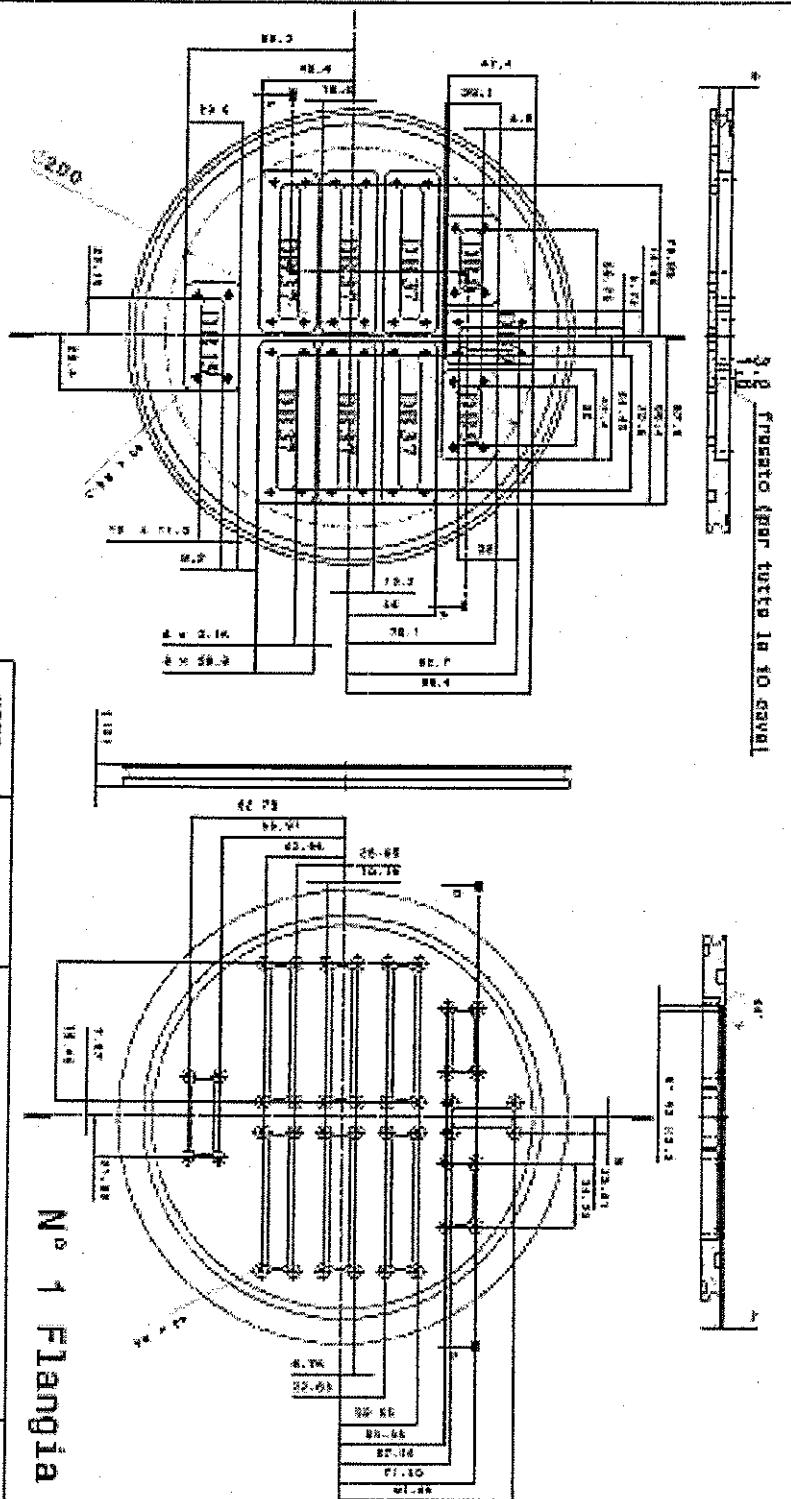
data: 20/12/05

rev: A03

pag 17 di 25

file: TVC\_Technical Report\_A03

Le piste segnano tutto sul centro del  
disco. Utilizzare solo questo cono  
riferimento.  
Tutto ciò che è al di fuori del cerchio  
di 200 m di diametro è riferito al  
solo cerchio indicativo.

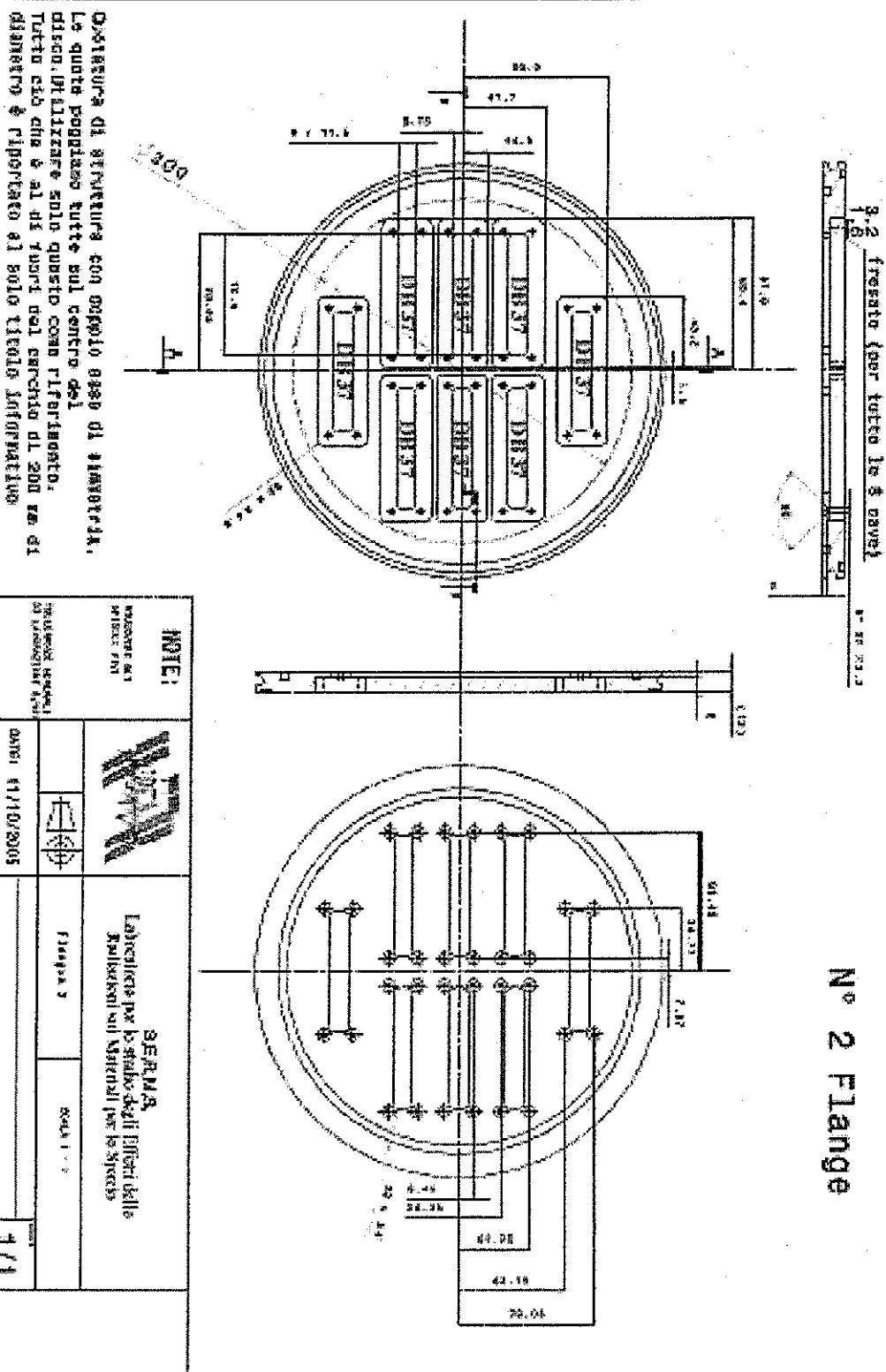


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# TECHNICAL REPORT

doc TVC\_Technical Report  
data: 20/12/05  
rev: A03  
pag 18 di 25  
file: TVC\_Technical Report\_A03



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# TECHNICAL REPORT

doc: TVC\_Technical Report  
data: 20/12/05  
rev: A03  
pag: 19 di 25  
file: TVC\_Technical Report\_A03

The technical characteristics, number and dimension of the feedthroughs mounted on the different flanges are reported in the following tables and figures:

Type	# of pins	I/F type	Type of contacts	Total # of feedthrough
DB 9	9	M/F (male vacuum side)	Normal Density	3
DB 15	15	M/F (male vacuum side)	Normal Density	1
DB 37	37	M/F (male vacuum side)	Normal Density	22
Total # of pins				856

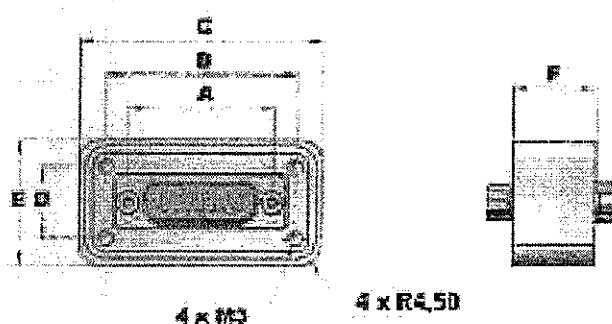


Figure 19 – Dimensions of the feedthrough.

	A	B	C	D	E	F
DB 9	24.99	34.29	46.37	16.00	28.08	18
DB 15	33.32	43.64	55.79	16.76	28.92	18
DB 37	63.50	73.46	85.38	16.90	28.82	18

N.B.: all the dimensions are in mm

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# TECHNICAL REPORT

doc. TVC\_Technical Report

data: 20/12/05

rev: A03

pag 20 di 25

file: TVC\_Technical Report\_A03

Mounting scheme and dimensions of the hole are reported in the next table and figure.

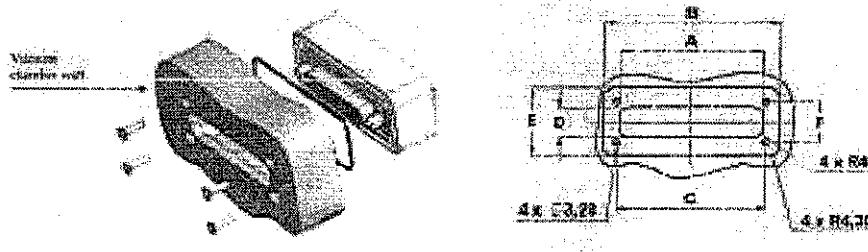


Figure 20 – Dimensions of the hole and mounting description.

	A	B	C	D	E	F
DB 9	32	47.4	34.29	11.50	29.10	16
DB 15	40.3	56.8	43.64	11.50	29.9	16.76
DB 37	70.50	86.40	73.46	11.50	29.80	16.90

N.B.: all the dimensions are in mm.

## MATERIALS AND FINISHES

- Insulator: Glass-filled DAP (ASTM-D-5948)  
Contacts: Precision machined high tensile copper alloy with stainless steel shrouds  
Contact plating: 0.000050 inch (1.25 micron) gold over copper plate  
Housing: Aluminium alloy  
O-ring: Viton

## ELECTRICAL CHARACTERISTICS

- Contact Current Rating: 7.5 A (nominal value)  
Initial contact resistance: 0.008 ohms maximum  
Working Voltage: 1000 V.r.m.s.

# TECHNICAL REPORT

doc. TVC\_Technical Report

data: 20/12/05

rev: A03

pag. 21 di 25

file: TVC\_Technical Report\_A03

## DESCRIPTION OF THE AVAILABLE CONNECTORS

D-Sub connectors vacuum-side (realized according to MIL-C-24308) are available:

- n° 22 D-Sub connectors with 37 pins
- n° 1 D-Sub connectors with 15 pin
- n° 3 D-Sub connectors with 9 pin

These connectors have the following characteristics:

<b>Material:</b>	Glass fibre reinforced polyetherimide UL94V0 with removable crimp contacts;
<b>Current rating:</b>	5A
<b>Test current between contacts:</b>	1200 V / 1 min
<b>Insulation resistance between contacts:</b>	> 5000 MOhm
<b>Maximum cable size:</b>	2.2 mm
<b>Mating cycles:</b>	> 500
<b>Heat deflection limit according to DIN HDT/A:</b>	197°C
<b>Relative temperature index according UL 746 B:</b>	130°C
<b>Sub temperature limit:</b>	- 55 °C

All the contact pins are crimp contacts. To crimp the cable the following tool are available at SERMS laboratory:

- Crimping tool M22520/2-01
- Positioner M22520/2-08
- Extraction tool M81969/1-02

To choose an adequate cable length, in the following figures the distances between the cold plates and their position respect to the flanges with the feedthrough are showed.

Minimum cable length suggested:

- 4 mt for test item placed on the lower cold plate;
- 5 mt for test item placed on the middle cold plate;
- 6 mt for test item placed on the upper cold plate.

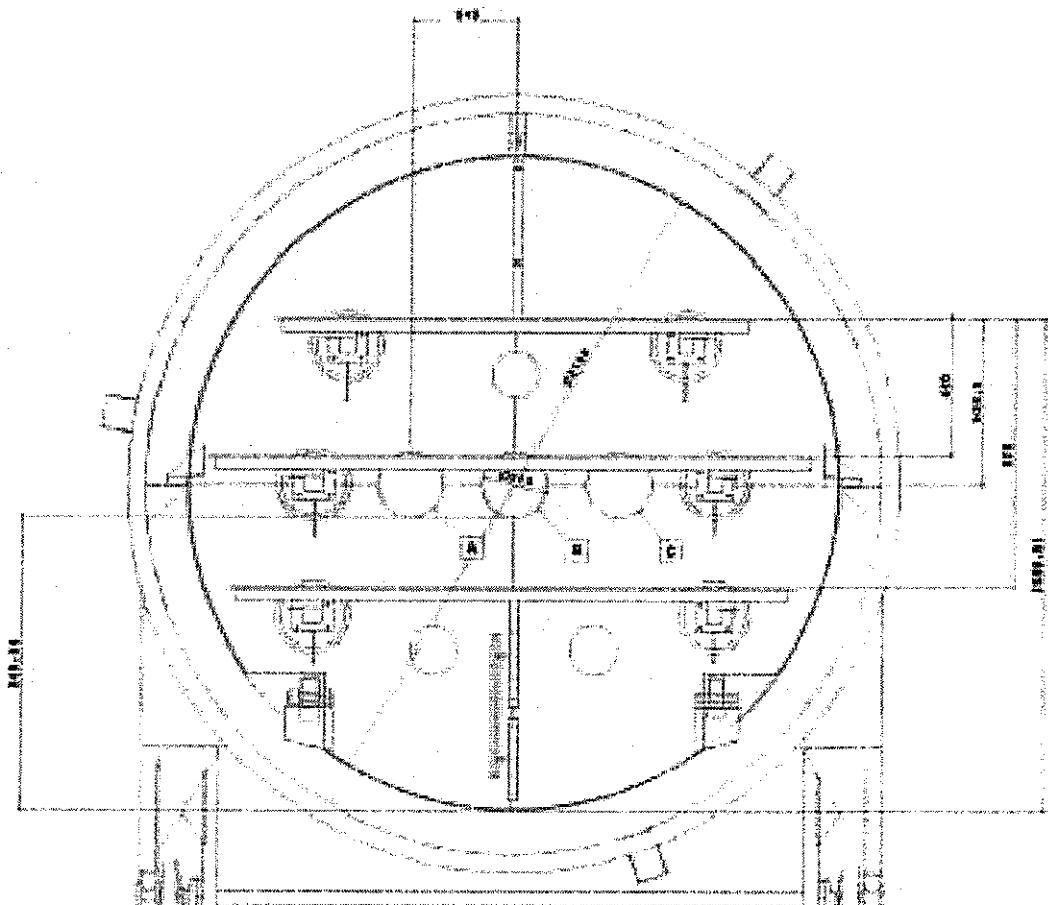
If a shorter length is needed, for a limited number of cable, it is possible to use a minimum cable length of about 2 mt (taking advantage of the holes on the shroud)

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# TECHNICAL REPORT

doc TVC\_Technical Report  
data: 20/12/05  
rev: A03  
pag 22 di 25  
file: TVC\_Technical Report\_A03



**A-B-C: Flange  
passacavi**

Figure 21 – Position of the cold plates respect to the flanges with the feedthrough.

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## TECHNICAL REPORT

doc: TVC\_Technical Report  
data: 20/12/05  
rev: A03  
pag 23 di 25  
file: TVC\_Technical Report\_A03

### DESCRIPTION OF THE AVAILABLE EQUIPMENT

At the SERMS laboratory heaters, strain gauges and PT100 sensors are available. In the following section a brief description of these sensors is reported.

#### Heaters

Two types of heaters are available; they differ for the electrical resistance and thus for the power that are able to dissipate.

They are all Kapton Heaters from MINCO supplier, suitable for vacuum environment (NASA-RP-1061). All the materials are NASA approved for space application (S-311-P-079).

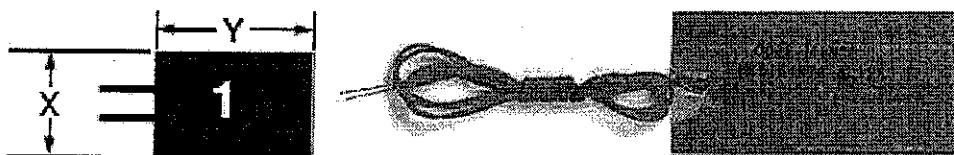


Figure 22 – Type configuration for the heaters.

In the following table the main characteristic and the number of heater available are reported.

Part #	# available	Size (mm) X - Y	Resistance m ohms	Typical power	Effective area (m <sup>2</sup> )	Lead AWG
HK5167R264L12A	2	25.4 254	264	50 W at 115 V	8.96	30
HK5165R52.3L12A	4	25.4 76.2	52.3	15 W at 28 V	2.70	30

# TECHNICAL REPORT

doc. TVC\_Technical Report

data: 20/12/05

rev: A03

pag. 24 di 25

file: TVC\_Technical Report\_A03

## Strain Gauges

A total amount of 20 bidirectional ( $0^\circ$ - $90^\circ$  T rosette) strain gauges (from HBM supplier-part # 1-XY31-3/120) are available. They have the following characteristics:

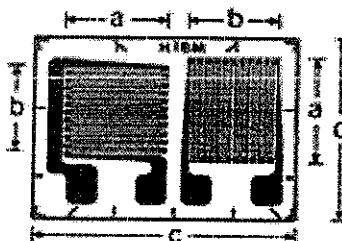


Figure 23 – Size of the strain gauges.

- Dimensions (mm) (see figure above)

Measuring grid

$$a = 3$$

$$b = 2.8$$

Measuring grid carrier

$$c = 10.5$$

$$d = 8$$

- Strain Gauges construction:

Measuring grid

Material

Constantan foil

Carrier

Material

polyimide

Thickness

$45 \pm 10 \mu\text{m}$

Cover

Material

polyimide

Thickness

$25 \pm 5 \mu\text{m}$

- Nominal resistance 120 Ohms

- Gage factor approx. 2

- Gage factor tolerance  $\pm 1 \%$

- Temperature response matched to steel  $10.8 \cdot 10^{-6} / \text{K}$

- Max. perm. Effective bridge excitation voltage 11 V

- Operating temperature range

For absolute, i.e. zero point related measurements  $-70 \div 200^\circ\text{C}$

For relative, i.e. not zero point related measurements  $-200 \div 200^\circ\text{C}$

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## **TECHNICAL REPORT**

doc TVC\_Technical Report  
data: 20/12/05  
rev: A03  
pag 25 di 25  
file: TVC\_Technical Report\_A03

### **Temperature sensors (PT100)**

A total amount of 50 PT100 test temperature sensors (from MINCO supplier – part # S249PD12) are available. All PT100s have  $100 \pm 0.12\%$  ohm platinum element; here there are the main characteristics of these sensors:

- Material	Ceramic/glass body, silver leads
- Dimensions	0.08" $\times$ 0.09" (2.0 $\times$ 2.3 mm)
- Thickness	1.4 mm
- Temperature range	-70 to 400°C
- Sampling frequency	0.008 Hz with 64 sensors (1 acquisition every 128 sec) 0.01 Hz with 50 sensors (1 acquisition every 100 sec)

### **Temperature controller**

One temperature controller is available (Watlow supplier – part # PDD1-CCCC-1AAA) to control the heaters temperature variation during the test. This controller has a dual channel input (PT100 sensors) and four output channel for the heaters. The guarantee temperature stability is  $\pm 0.1$  °C/°C, while the update rates are 10 Hz for both input and output. Together with this controlled, four SSR can be used (supplier Watlow – n° 2 part # SSR-240-10A-DC1 – n° 2 part # SSR-100-20A-DC1).

Two of them are able to control a maximum current value of 10A, with an output tension of 120/240 vdc/vac, the other a maximum current of 20A with an output voltage from 0 to 100 vdc.

### **Cho-Term - Thermally conductive elastomer insulator**

A roll 74,2mm x 122 mt without adhesive of Cho-Term 1674 (from Chomerics) is available (part # 64-40-0300-1674). It is an aluminium oxide-filled silicone elastomer designed for applications which require good heat transfer performance and moderate electrical isolation characteristics. It is reinforced with fibreglass cloth to provide maximum resistance to tear, cut-through and punctures due to burrs and other mating surface irregularities. Using this insulator both a good heat flow from the device to the metal heat sink and electrical isolation of the device from the metal heat sink can be achieved. This insulator has a thickness of 0.25 mm (0,01 inch), a thermal impedance of  $2.6$  °C – cm<sup>2</sup>/W, a thermal conductivity of 1.0 W/m K and an operating temperature range from -60°C to 200°C.